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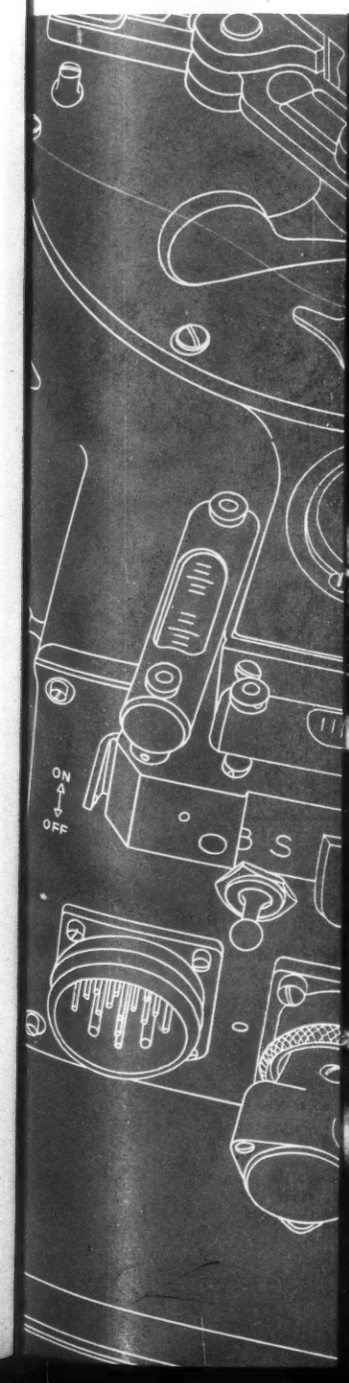
MACHINE DESIGN

February 1946



In This Issue:

Designing for Magnesium

Supersensitive Balancing

The Manual starter built on the premise *all* motors deserve equal protection

Although the Cutler-Hammer 9115 starter is built for motors that can be manually started, it has the same design, construction and operational features that have made Cutler-Hammer Magnetic Starters a standard wherever electric motors are used. Here you will find the same "drop-of-solder" eutectic alloy overload relay that distinguishes the Cutler-Hammer Magnetic Starter line . . . the same twin-break Vertical dust-safe contacts . . . the same pure, fine silver contact faces . . . the same snap action contact mechanism . . . the same simple design . . . the same dependability . . . the same attractive, clean styling. Only in the absence of the electro-magnetic closing mechanism is there any difference at all. Every motor in your plant no matter how small or "unimportant" has an essential role to play in production. Every motor deserves equal care and protection. Every manually started motor deserves *this* degree of protection. Yet C-H 9115 costs no more than ordinary starters. CUTLER-HAMMER, Inc., 1310 St. Paul Ave., Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ont.

CUTLER-HAMMER
MOTOR CONTROL
C-H

CASE—Modern styling and design. Standard NEMA type 1 enclosure. 8 x 4¾ x 4. Japanned steel. Interior light finish for high visibility. Cover can be padlocked. Knockouts top and bottom. Ample space, complete accessibility.

OPERATING MECHANISM—Available as skeleton for building into machines, etc. Metal parts rust-proof. Rubber mounting absorbs shocks. Mechanism removable as a unit by loosening one screw—for wiring, etc. Parts and terminals easily accessible.

COVER—"Hook-on" type. Loosening one screw permits lifting off from front. Permits close-fit installation.

CONTACT STRUCTURE—Newly designed for compactness, simplicity, strength and accessibility. Unit base construction easily removed. Positive, quick-make, quick-break, twin-break silver-to-silver contacts mounted on unit base.

OVERLOAD RELAY—Famous C-H eutectic alloy thermal overload relay, most dependable known. Reset by pushing top button. Free-tripping. Rating changed by changing heater coils.

PUSH BUTTON OPERATION—An achievement for this type of starter. Has start, stop-and-overload reset buttons. Start button can be locked to prevent unauthorized operation.

DETAILS—As further evidence of the extreme care and thought in designing this new starter, your attention is called to numerous small yet important details such as self-finding terminal screws, unique staking of cover screw, handy spring lifters on movable contacts, etc., etc.

MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

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CONTENTS

February, 1946 — Volume 18 Number 2

Cover—Norden Bombsight (Courtesy of Victor Adding Machine Co.)

Itemized Index 7

Topics 98

Magnesium Die Castings—Part I—General Design 101
By Ralph M. Heintz

Scanning the Field for Ideas 105

Design of Supersensitive Balancing Equipment 109
By Karl F. Frank

Photoelasticity Solves a Knotty Snap-Ring Problem 115
By R. E. Orton

Production Processes—Part VIII—Swiss Automatic Machining 117
By R. W. Bolz

Brazed Stampings Reduce Engine Weight 123
By Paul Klotsch

Standardization Pays Dividends 126
By B. C. Boulton

Solving Complex Problems by Electrical Analogy—Part II 129
By G. D. McCann and H. E. Criner

Drafting-Room Practice 133

Designing Computing Mechanisms—Part VII—Stepping Followups 137
By Macon Fry

Life Quality Predictions by Statistical Methods 141
By Enoch B. Ferrell

Why Not Incentive Bonuses? (Editorial) 145

Outstanding Designs 146

Applications—of Engineering Parts, Materials and Processes 148

Nomogram Facilitates Helical Spring Design (Data Sheet) 149
By Carl P. Nachod

Heat and Corrosion-Resistant Cast Steels (Materials Work Sheet) 151

Professional Viewpoints 158

New Parts, Materials and Equipment 159

Noteworthy Patents 168

Men of Machines 172

Design Abstracts 176

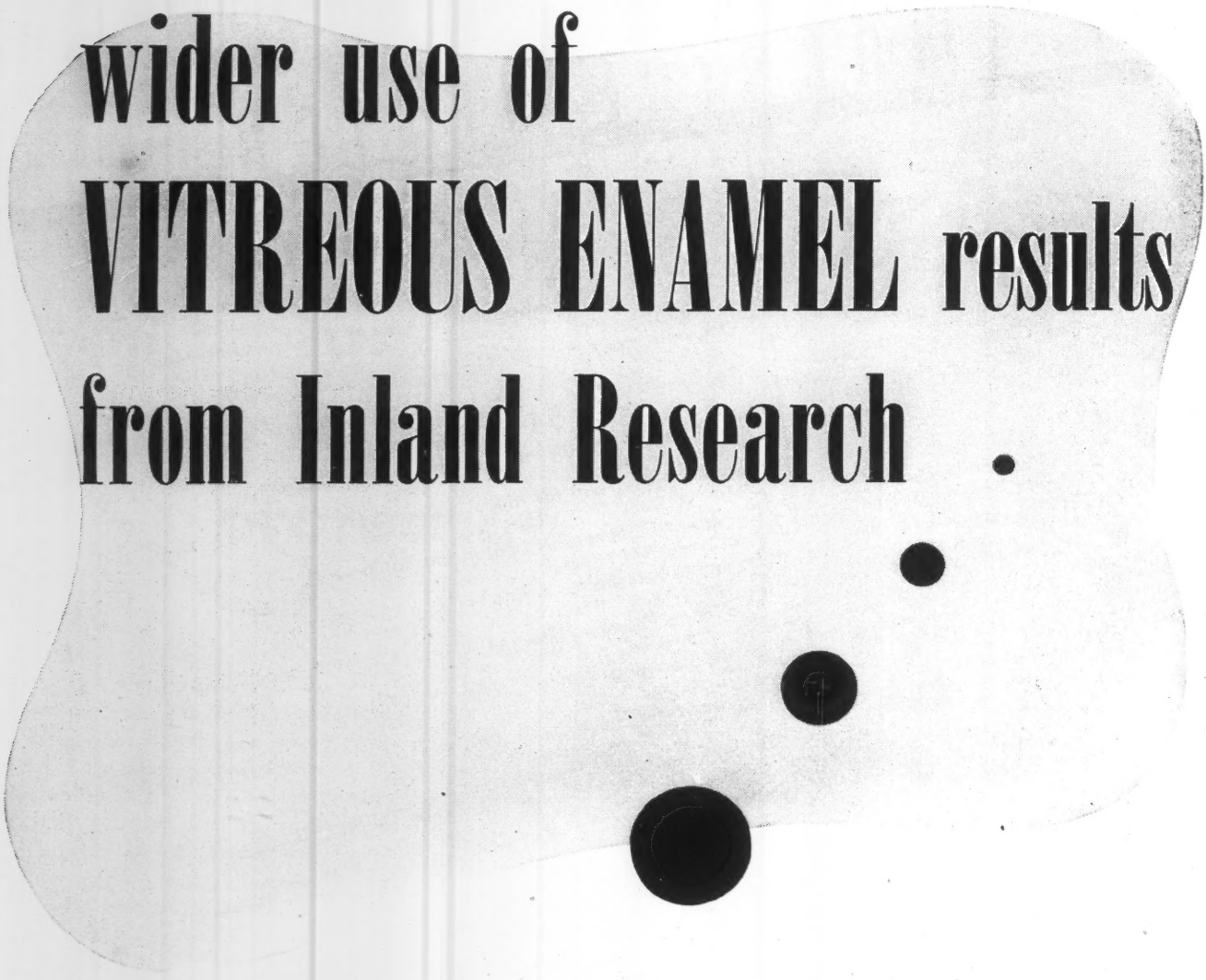
Business and Sales Briefs 184

Calendar of Meetings 190

New Machines 192

Helpful Literature 333

wider use of VITREOUS ENAMEL results from Inland Research



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Itemized Index

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Design and Calculations

Balancing equipment, Edit. 109-114, 180, 182
Computing mechanisms, Edit. 137-140
Constant tension drive, Edit. 107
Control, mechanical, Edit. 107
Die castings, Edit. 101-104, 180
Helical springs, Edit. 149-150
Stampings in engine design, Edit. 123-125
Standardization in design, Edit. 126-128
Statistical methods of test, Edit. 141-144
Stress analysis, Edit. 115-116
Swiss automatic machining, Edit. 117-122
Transient analyzer, Edit. 129-132, 157

Engineering Department

Design service, Adv. 312, 345, 351
Equipment, Edit. 106; Adv. 18, 61, 200, 201, 308
Management, Edit. 126-128, 133-136, 158, 177, 178
Supplies, Adv. 193, 276, 330, 338, 348

Finishes

Electroplating, Adv. 92
Lacquer, Adv. 248
Synthetic, Adv. 87

Materials

Aluminum alloys, Adv. 31, 63
Babbitt, Adv. 332
Bronze, Adv. 267
Ceramics, Edit. 178
Copper alloys, Adv 34, 252
Felt, Adv. 280
Fiber, Adv. 297
Glass, Edit. 108
Magnesium alloys, Adv. 14, 15, 48
Molybdenum alloys, Adv. 187
Nickel alloys, Adv. 59, 221
Plastics, Adv. 28, 58, 167, 211, 306
Rubber and synthetics, Adv. 32, 49, 213, 217
Steel, Edit. 98, 151-156; Adv. 4, 41, 204, 214, 215, 305
Steel, stainless, Adv. 50, 51, 181, 195
Zinc, Adv. 169

Parts

Balls, Adv. 336
Bearings:
- Ball, Edit. 160, 162; Adv. 73, 76, 79, 207, 269, 358
- Needle, Adv. 47
- Roller, Adv. 11, 202, 242, 282, Back Cover
- Sleeve, Adv. 36, 64, 84, 165, 184, 270, 331, 343, 365

Bellows, Adv. 8
Belts, Adv. 26, 243, 257, 286
Cable controls, Adv. 289, 343, 348
Cams, Adv. 340
Carbon parts, Adv. 85, 320, 356
Castings:
- Die, Edit. 101-104, 180; Adv. 38, 44
- Investment, Adv. 66, 285
- Sand, Adv. 96, 225, 239, 247, 260

Chains, roller, Adv. 22, 35, 42, 86, 89, 228
Clutches, Adv. 93, 266, 302, 317, 354, 361
Controls (see Electric, Cable, etc.)
Counters, Edit. 108; Adv. 283, 328
Couplings, Edit. 168; Adv. 212, 355
Cylinders, Adv. 329
Dials, Adv. 314
Diaphragms, Edit. 148
Electric accessories, Adv. 340
Electric controls:
- Capacitors, Adv. 97
- Contactors, Edit. 160
- Contacts, Adv. 188
- Control assemblies, Adv. 226, 227
- Electronic, Edit. 107, 144
- Rectifiers, Edit. 164, 166
- Relays, Adv. 240, 265
- Resistors, Edit. 164
- Rheostats, Adv. 277
- Solenoids, Edit. 148; Adv. 197
- Starters, Adv. Inside Front Cover, 198 303
- Switches, Edit. 160, 162, 166; Adv. 82, 309, 330, 342
- Thermostats, Adv. 224, 347
- Timers, Edit. 161; Adv. 320
- Voltage regulators, Adv. 295

Electric converter, Adv. 344
Electric generator, Edit. 161; Adv. 338
Electric motors, Edit. 105, 159; Adv. 6, 20, 53, 67, 68, 77, 81, 185, 220, 250, 284, 314, 319, 322, 325, 350, 353, 359
Engines, Edit. 123-125; Adv. 12, 186, 216, 336
Expanded metal, Adv. 189
Fabricated parts, Adv. 88, 344
Fastenings:
- Belt, Adv. 337
- Locking, Edit. 115-116, 162; Adv. 1, 55, 338, 348, 355
- Nuts, bolts, screws, Edit. 126; Adv. 16, 17, 54, 60, 175, 182, 191, 208, 209, 296, 304, 341, 346, 357, 366
- Rivets, Edit. 161, 164
- Studs, Adv. 205

Felt parts, Adv. 24, 245
Filters, Edit. 160; Adv. 27, 249, 300
Fittings, Edit. 128; Adv. 69, 75, 179
Forgings, Adv. 33, 223, 241, 258, 281, 324, 326, 357, 361
Gears, Adv. 5, 18, 29, 62, 190, 222, 236, 324, 330, 337, 343, 345, 349, 361
Generators (see Electric generators)
Hydraulic and pneumatic equipment:
- Accumulators, Edit. 166; Adv. 313
- Controls, Adv. 99
- Cylinders, Adv. 22, 192, 261, 275, 335, 339
- Pumps, Edit. 159, 168; Adv. 23, 196, 278, 341
- Systems, Adv. 9, 74, 90, 256, 293, 323, 359
- Valves, Edit. 159, 164; Adv. 100, 219, 291, 307, 336

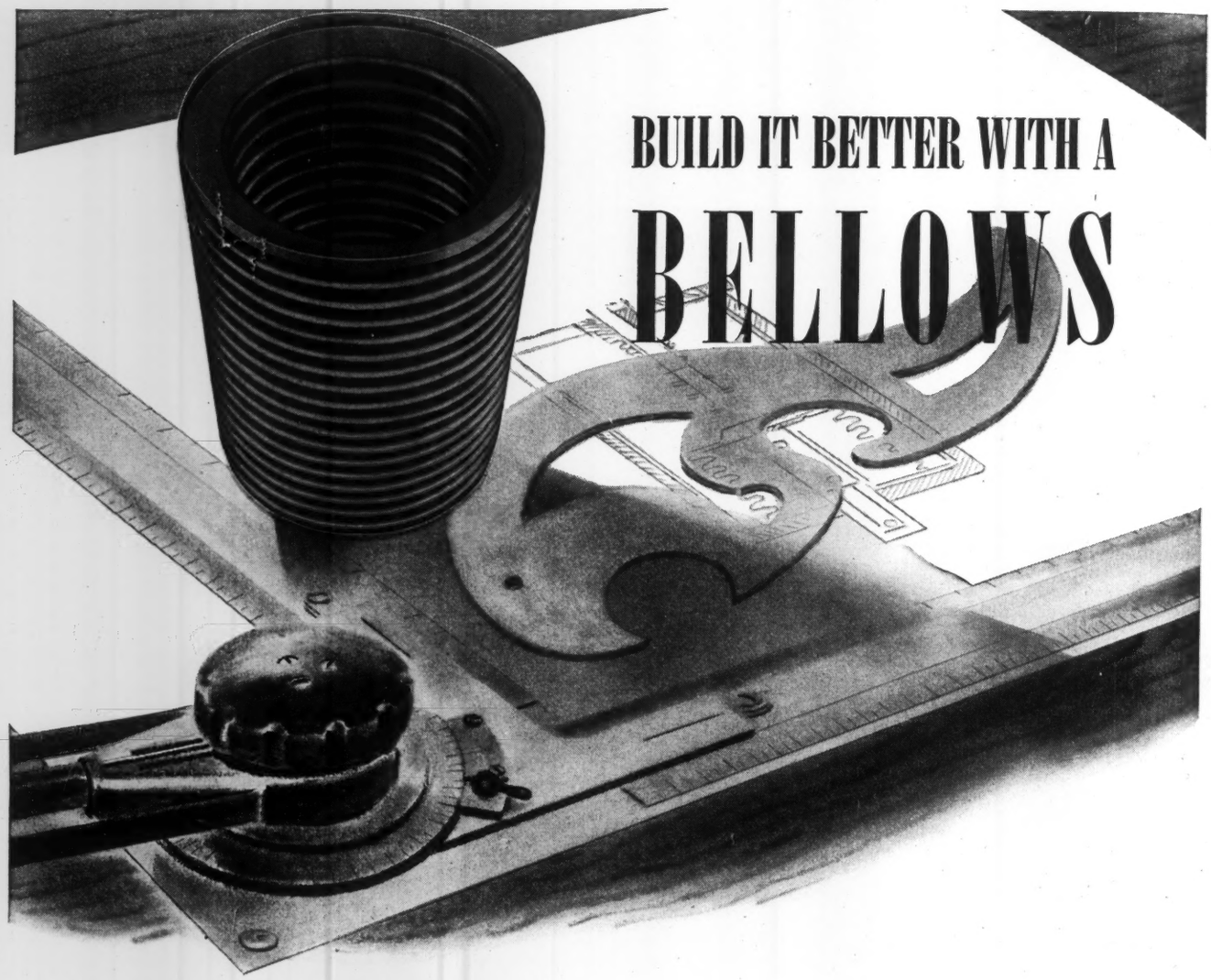
Indexing control, Edit. 170
Instruments, Edit. 106; Adv. 21
Insulation, Adv. 233
Joints, Adv. 251, 341, 351
Lamps and lighting, Edit. 166
Locks, Adv. 299
Lubrication and equipment, Adv. 177, 315, 342, 349
Machined parts, Adv. 318, 321, 358
Mechanical controls, Edit. 107
Motors (see Electric motors)
Mountings (rubber) Adv. 65
Pins, dowel, Adv. 316
Plastic parts, Adv. 40, 183, 292, 326, 347, 352
Plugs, Adv. 78
Pneumatic equipment (see Hydraulic and pneumatic)
Powder-metal parts, Adv. 91, 206, 264
Pulleys and sheaves, Edit. 126; Adv. 39, 71, 274
Pumps (see also Hydraulic and pneumatic), Adv. 30, 70, 72, 316, 339 351, 352, 355, 356, 358
Rings, retaining, Adv. 238
Rubber and synthetic parts, Edit. 45, 57; Adv. 10, 234
Seals, packings, gaskets, Edit. 161, 162; Adv. 171, 173, 203, 231, 246, 290, 312, 363
Shafts, flexible, Adv. 353, 357
Sheet-metal parts, Adv. 218
Speed reducers, Adv. 13, 83, 94, 95, 268, 287, 301, 345, 346, 352
Spindles, Adv. 354
Springs, Edit. 149-150; Adv. 80, 229, 244, 254, 262, 288, 340, 350
Stampings, Edit. 123-125; Adv. 52, 255, 279, 339, 356
Static eliminator, Adv. 253
Transmissions, variable speed, Adv. 298, 347, Inside Back Cover
Tubing:
- Assemblies, Adv. 337
- Metallic, Adv. 210, 232, 237, 259, 263, 322

Universal joints, Adv. 194, 318, 329
Valves (see also Hydraulic and pneumatic), Adv. 46
Weldments and equipment, Adv. 37, 199, 235, 272, 273, 311, 359
Wheels and casters, Edit. 164; Adv. 328, 354
Wire and wire products, Adv. 43, 327

Production

Balancing, Adv. 344
Cleaning, Edit. 106
Facilities, general, Adv. 310
Induction heating, Adv. 271
Machining, Swiss automatic, Edit. 117-122
Packaging, Adv. 56
Sealing, hermetic, Adv. 294
Spinning, Edit. 148
Testing and equipment, Edit. 109-114, 180, 182
Tools and accessories, Adv. 25, 230, 342, 353

MACHINE DESIGN is indexed in Industrial Arts Index and Engineering Index Service, both available in libraries generally.



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This removable mounting bracket is now available for most G-E rectangular a-c and d-c capacitors, permitting the capacitor to be mounted upright or inverted.
1. Provides "spring-washer" effect for secure capacitor mounting.
2. Reduces strain on capacitor and chassis.
3. Compensates for manufacturing tolerances in height of case.

In contrast with the conventional L-shaped bracket, this U-bend construction minimizes the stress on the metal chassis and prevents distortion when mounting bolts are tightened. The mounting foot is sufficiently flexible to compensate for normal tolerances in height of case, and for variations in dimensions of the bracket itself.

The brackets are sufficiently thick to provide strong, rigid support. A corrosion-resistant finish of lacquered zinc plate assures a good ground from capacitor to chassis. The brackets have either one or two mounting holes depending upon the width of the capacitor.

These brackets are an exclusive feature on G-E capacitors. Spade-type and L-shaped brackets can still be obtained when desired. Ask for Bulletin GEA-4357 for information on the G-E capacitors that can now be furnished with this improved feature. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

GE CAPACITORS

GENERAL ELECTRIC

407-96-5700

Topics

POTENTIAL ABILITY of the world to produce natural rubber is much the same as before the war—approximately 1,600,000 tons. Added to this production, 1,400,000 tons of synthetics gives a total of 3,000,000. Most careful estimates of consumption, according to John L. Collyer, president of the Goodrich company, is only half this combined tonnage. The problem of approaching surplus should be carefully solved to give military security, best products and lowest costs.

FOR TESTING JET ENGINES, General Electric installed an I-40 jet in the fuselage of a B-24. These observations under actual flying conditions provide facilities and advantages of wind tunnel data with considerably less cost and greater availability. The "flying laboratory" also is a means of acquainting design engineers with the problems attendant to flying and with operation of their design in flight. Use of the B-24 allows flight space to observe operations.

ALMOST EVERY AMERICAN home will be equipped with a second refrigerator or a combination refrigerator-freezer within the next five years, according to James H. Carmine, vice president of Philco Corp.

APPROACH-ANGLE indicator enables a pilot to virtually glide to a landing on a beam of light. Placed at the end of the runway, the unit projects three colored beams toward an approaching plane. The top beam is amber with an eight-degree included angle. Middle one is a two-degree green beam, and the bottom is a six-degree red light. Remarkable beam fidelity is obtained from the system which contains a reflector, a 100-watt single-plane filament, a series of five clear lenses, and three color filters.

BASED ON the principle that a propeller loses its thrust efficiency at high speeds while a pure jet engine becomes more efficient, the XP-81 long range plane was built by Consolidated-Vultee Aircraft as the longest-range jet fighter thus far developed. With a propeller in front and a jet engine in the rear the plane can operate on either engine or both. A gas turbine converts jet power into rotational energy to drive the 4-bladed propeller in the nose. Additional thrust is developed from its exhaust jet. An I-40 jet engine similar to that used in the P-80 Shooting Star, is used in the rear.

VELOCITIES of the order of 22,000 feet per second or more than 14,000 miles an hour will have to be attained to shoot a rocket across the Atlantic Ocean, according to G. Edward Pendray of the American Rocket Society. At these velocities a rocket would traverse the whole distance from London to New York in a little over 14 minutes trajectory time. German V-2 rockets exceeded 3600 miles per hour at some portions of the flight.

HIGH-STRENGTH ALUMINUM alloys of the aluminum-manganese-zinc-copper type recently perfected in this country were found to have been used extensively in captured Jap Zero planes.

DOCUMENTARY RECORD of the German Air Force ultimately will be made public. Weighing more than 250 tons this vast library will tell the American People more about the Luftwaffe than the Germans themselves knew.

SURPLUS airplane gasoline tanks are finding wide usage including feed and water troughs, fishing boats, duck blinds, storage containers, sand boxes for children, pontoons to support pipelines across water, outdoor showers, irrigation tanks, and brooder houses for baby chicks. A sales plan tested at Des Moines, Iowa disposed of 75 carloads of bulletproof and synthetic-rubber tanks in a seven-day sale.

LEAD-PLATED STRIP, in graduated thickness of coating, is being utilized to test the corrosivity of used lubricating oils from internal-combustion engines. Strip is copper plated with lead in steps of varying thickness from 0.00003 to 0.001-inch. Test involves immersion in the oil for a definite period to determine the extent to which the lead plate is removed.

MACHINE DESIGN

Magnesium DIE CASTINGS

Part I—General Design

By Ralph M. Heintz
Vice President and Secretary
Jack & Heintz Inc.

WHEN undertaking the design of a magnesium die casting, it generally is best to start from scratch rather than try to adapt a piece already designed for sand casting. A designer is bound to be influenced or possibly prejudiced by sand casting technique and his die casting design may suffer thereby. For example, when designing a part to be sand cast it is

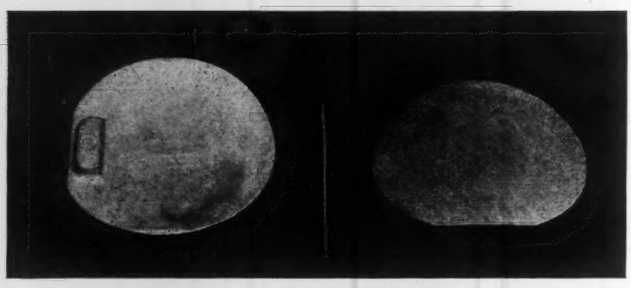


Fig. 1—Shield for aircraft gyro instrument, die-cast of magnesium, is extremely light, yet has good strength

customary to make allowances for core shifts, loose flask pins, rapping, etc. In addition, allowances must be made for rather heavy draft, large fillets, minimum metal thickness, shrinkage of thick sections, variations in shrinkage with pouring temperature, and warpage due to heat treatment.

As a result the designer has learned to provide for the removal of large amounts of metal at machined surfaces (see head picture) and for bosses large enough to insure an acceptable minimum of metal around a stud or screw when a maximum accumulation of errors is encountered. In the case of die casting, the designer can forget most of these limitations. This will be appreciated more fully after comparing the characteristics of the two casting processes listed in TABLE I.

TABLE I

Comparative Design Factors of Die-Cast and Sand-Cast Magnesium

	Die Casting	Sand Casting
Tolerance (average per in. of dimension)	0.0015	0.063
Minimum diameter of hole (inches)	0.062	0.25
Maximum depth of hole	10 × diam of hole	Limited by draft or must be cored
Draft of outside walls (min, in./in.)	0.000–0.005	0.04–0.05
Draft of inside walls (min, in./in.)	0.010–0.015	0.04–0.05
Draft of holes (min, in./in.)	0.005–0.030	0.03–0.07
Section thickness (min, inches)	0.040	5/32
Shrinkage (inches per foot)	1/16	11/64

Ordinarily, a die-cast machine part of magnesium falls into one of four classes:

1. Decorative—appearance factors primary
2. Functional—strength secondary to lightness and cost
3. Structural—parts moderately stressed
4. Stressed—highest physicals required

DECORATIVE: Where strength is of little importance, such as microphone housings, grills, dials, moldings, and the like; seldom coupled with corrosion resistance. In most cases the "decorative" piece can be made as a die casting from the standpoint of cost alone, but in some cases the lightness of the metal is the controlling factor. A simple example is shown in *Fig.* 1. This is a shield used in an aircraft gyro instrument. Besides being the most inexpensive way of making this piece, magnesium is the best material for the job because of its lightness. The shield is fastened to a gymbal which is sentive to inertia forces. Thus, by making the shield of magnesium and very thin, its contribution to the moment of inertia of the gymbal system is negligible. While the piece is but 0.04-inch thick, it cannot be broken in the hands of a full-sized man.

FUNCTIONAL: Where strength is of secondary importance to lightness, rigidity, or cost, as in household appliances, typewriter frames, hand tools, radio equipment, etc., sometimes coupled with corrosion resistance. Also, appearance usually is a factor. An example of functional design is shown in *Fig.* 2. This piece is the chassis or "crab" of a gyro-pilot unit and serves excellently to illustrate an item of design wherein strength is of secondary importance, for the design revolves almost entirely around the low Young's modulus. No great stresses are imposed on this piece but it is important to keep the bearings aligned

TABLE II

Specifications and Properties of Most Widely Used Magnesium Die Casting Alloy

SPECIFICATIONS

Army/Navy AN-M-16	Navy Dept. 46-M-11	ASTM B94-41T	SAE 501
AMS 4490	Dow Chem. Corp. "R"	Am. Mg. Corp. AM-263	

CHEMICAL COMPOSITION (per cent)

Al	8.5–9.5	Cu (max)	0.04
Mn (min)	0.15	Ni (max)	0.01
Zn	0.5–0.9	Other Impurities (max)	0.30
Si (max)	0.2	Mg	Remainder

MECHANICAL PROPERTIES (typical)

Ultimate Tensile Strength (psi)	33,000
Ultimate Compressive Strength (psi)	58,000
Ultimate Shear Strength (psi)	20,000
Tensile Yield Strength (psi)	22,000
Compressive Yield Strength (psi)	22,000
Shear Yield Strength (psi)	14,000
Elongation in 2 inches (%)	3
Rockwell "E" Hardness	72
Fatigue Strength—500 × 10^6 cycles (psi)	14,000
Izod Impact (ft-lb)	2

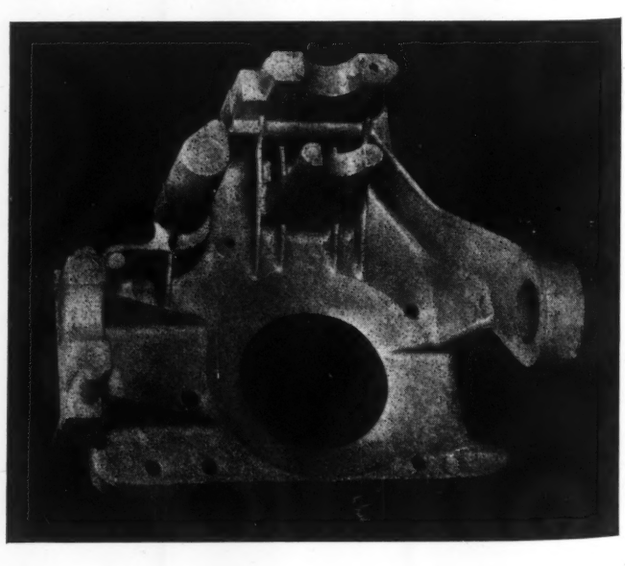
PHYSICAL PROPERTIES

Young's Modulus (psi)	6,500,000
Thermal Expansion, 65 to 750 F (deg F × 10^{-6})	1.6
Thermal Conductivity (cal/sec/cm²/cm/deg C)	0.17
Specific Heat (cal/g/deg C)	0.249
Electrical Resistivity (microhms/cm³ at 68 F)	17.0
Specific Gravity	1.81
Specific Weight (lb/in³)	0.063
Melting Point (deg F)	1120

RELATIVE WEIGHT (Mg alloy = 1.0)

Aluminum Alloys	1.6	Steel	4.4
Zinc	3.9	Brass	4.7
Cast Iron	4.0	Bronze	4.9

Fig. 2—Example of functional design is this gyro-pilot "crab" wherein low Young's modulus is primary requisite



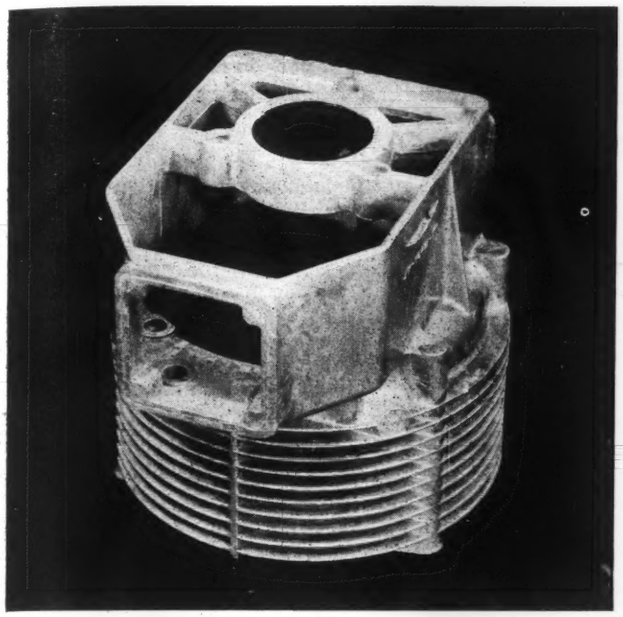


Fig. 3—Above—Motor housing for B-29 landing gear retraction unit is example of structural design in which strength is required

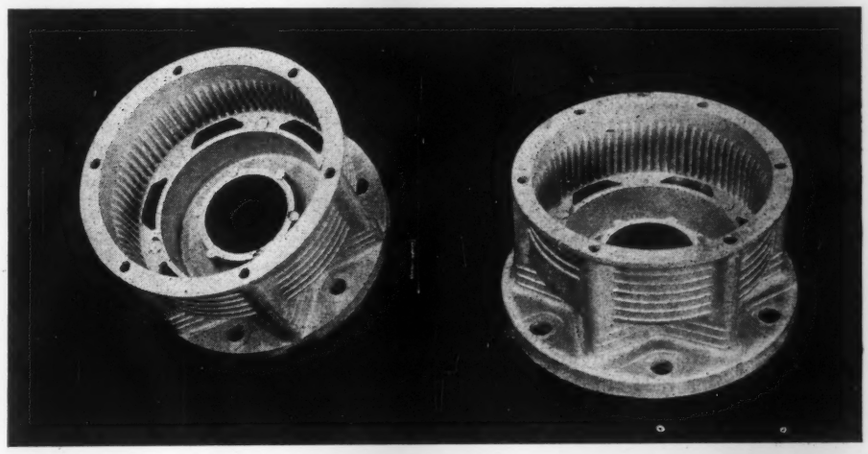


Fig. 4—Right—Base for engine starter exemplifies stressed design. When mounted, this part is placed under compression by long bolts and withstands severe vibration

and insure that the various elements assembled to the crab keep their relative positions. By the time the several knees, brackets, braces, ribs and fillets are in place to insure comparative rigidity, the strength has far surpassed that actually needed. This often happens in functional design.

STRUCTURAL: Where strength is important, generally coupled with corrosion resistance as in some instrument elements, frames, housings and other machine parts subject to moderate stress. An example of structural application is shown in *Fig.* 3. This is a motor housing for the B-29 landing gear retraction unit. In this case ribbing serves the dual purpose of helping the cooling and stiffening the structure against the expanding force attending pressing-in of the stator structure. Here lightness is important not only in the overall saving in weight but because of the reduction in the polar moment of inertia of the whole unit (which is quite long) taken from the mounting flange. Corrosion resistance is also important as the unit is exposed to the weather.

STRESSED: Where the highest physical properties are demanded, nearly always coupled with abrasion resistance and resistance to fatigue and impact. Such applications would include machine and engine parts, impellers, fans, aircraft structure and the like. In some cases the good bearing qualities are put to use. A heavily stressed piece is shown in *Fig.* 4. This is a base for a starter for the largest engines in use. Being mounted directly on the engine the stresses due to vibration are enormous, but magnesium in this application has survived the most tortuous and destructive vibration tests that could be made in the laboratory. Under similar tests, forged steel bases have been known to fail.

It will be noted that long bolts place the magnesium under compression for the whole length of the shell, which makes effective use of its relatively high compressive strength. A valuable and often overlooked property aids in combating severe vibration, and that is the relatively high elastic hysteresis, which helps in damping.

This is also an excellent example of the maximum usefulness of die casting in shortening or eliminating machine work. All of the bolt holes and reliefs are cast to size. It will be noted that splined teeth which engage the clutch plates are cast-in to size. The machining operations are reduced simply to boring and facing.

Before entering into more detailed phases of design, some specific data on magnesium for die casting seems in order. These, including the specifications of the various specifying agencies, are listed in TABLE II. An appraisal of die-cast magnesium as a structural material is presented in TABLE III.

Process Saves Considerable Machining

Getting down to specific cases, the motor shell shown at the right of the head illustration is sand-cast and weighs, as cast, 2.30 pounds. This piece follows the usual design practice for sand casting. Metal match plates and core boxes as well as production in molding machines are assumed. The pile of chips next to this piece illustrates the metal that is removed by machining as compared with the substituted die casting shown at the left in the picture. Besides this, the finished weight of the sand casting is 1.75 pounds and die casting 1.35 pounds. The die casting has 27 holes as well as 16 reliefs, bosses, pads, etc., that must be drilled or machined in the sand casting. A steel bearing liner is cast into the die casting that must be shrunk into the sand casting. (This housing happens to be an

aluminum casting but serves for illustration). The figures listed in TABLE IV apply to this casting as produced of magnesium.

The sand casting price, including all foundry charges, is given at $1.00 per pound as compared with the die casting cost of $0.47 per pound. Total pattern charges of $3,000 and die charges of $10,000 are assumed to be amortized over 100,000 pieces. These are not actual prices, however, they are average for a casting of this type and will serve for comparison in this example.

KNOCK OUTS: Just about the time a designer thinks he is all set on a design, the die caster or die maker will mess things up by asking for "knock outs" or ejector bosses at the most inconvient places. It is well to see him early in the design stage and patiently work out with him the location of the knock outs where they will do the least harm and at the same time be most effective.

TABLE III

General Characteristics of Die-Cast Magnesium

	Excellent	Good	Fair	Poor
Piece Cost	...	x	...	...
Machinability	x	...	...	...
Die Life	...	x	...	...
Tensile Strength	...	...	x	...
Compressive Strength	...	x	...	...
Shear Strength	...	...	...	x
Elongation	...	...	x	...
Bearing Properties*	x	...	...	...
Lightness	x	...	...	...
Hardness	...	...	x	...
Young's Modulus	...	...	...	x
Thermal Conductivity	...	...	x	...
Electrical Conductivity	...	...	...	x
Corrosion Resistance	...	...	x	...
Strength at High Temperatures	...	...	x	...
Fatigue Strength	...	x	...	...
Impact Strength	...	...	...	x

*Against hardened shafts.

CAST-IN INSERTS: Ferrous and nonferrous inserts can be used freely. A coarse knurl is all that is needed for structure, but if the insert is to be leak-proof in addition, one or two grooves well below the knurl usually will suffice.

Hardened inserts can be used and still maintain a hardness of 45 rockwell C or better after casting. In cases where extreme hardness is needed (as, for example, a pump cylinder liner), nitrided inserts can be used to advantage.

Other inserts such as struts can be cast-in for strength or for expansion control. In cases where electrolytic corrosion results from the use of nonferrous inserts such as brass or bronze, this corrosion can be minimized by chrome plating.

CORED HOLES: Simple or intricate holes can be cast-in but generally the length should not exceed ten times the diameter for a free-end punch, and the draft in the case of such long punches should exceed 0.025-inch per inch. If very long holes, say 5/16-inch diameter by 10 or 12 inches in length are to be cored-in, the punches should be supported by side punches as shown in *Fig.* 5. Ordinarily holes smaller than 3/32-inch are not worth coring-in unless the piece is small.

FILLETS AND RADII: Fillets should be ample especially where thick sections join thin sections. A good rule to follow is to make the radius of the fillet at least as much as the thinner of the two sections joined at the fillet. A fillet with a radius equal to the thickness of the section may be considered adequate; of twice the thickness as ample and three times the thickness as extreme.

External radii such as the tops of ribs should have ample radii at the corners. This helps smooth filling of the die cavity by reducing turbulence. In the case of ribs, a full radius equal to half of the rib's thickness is customary.

TABLE IV

Comparative Weights and Costs of Typical Magnesium Part as Sand Cast and Die Cast

	—Sand Casting—		—Die Casting—	
	Costs	Weights	Costs	Weights
Piece as cast	$2.30	2.30 lb	$0.68	1.45 lb
Weight finished	...	1.75 lb	...	1.35 lb
Waste	...	.55 lb	...	0.10 lb
Machining	2.37*	.....	0.87†	.....
Shrinkage	0.23	.....	0.09	.....
Painting	0.04	.....	0.04	.....
Bearing Liner	0.27	.....	0.02	.....
Pattern and Die Charge	0.03	.....	0.10	.....
Cost of Finished Piece	$5.24		$1.80	

*Cost based on 33-minute machining time.
†Cost based on 6.5-minute machining time.

As a general design rule, sharp corners should be avoided and if possible eliminated except where an abrupt change of section is necessary to meet a design requirement. Sharp corners erode and burn away quickly and since this action only serves to round the corners anyway, why not take care

(*Concluded on Page* 180)

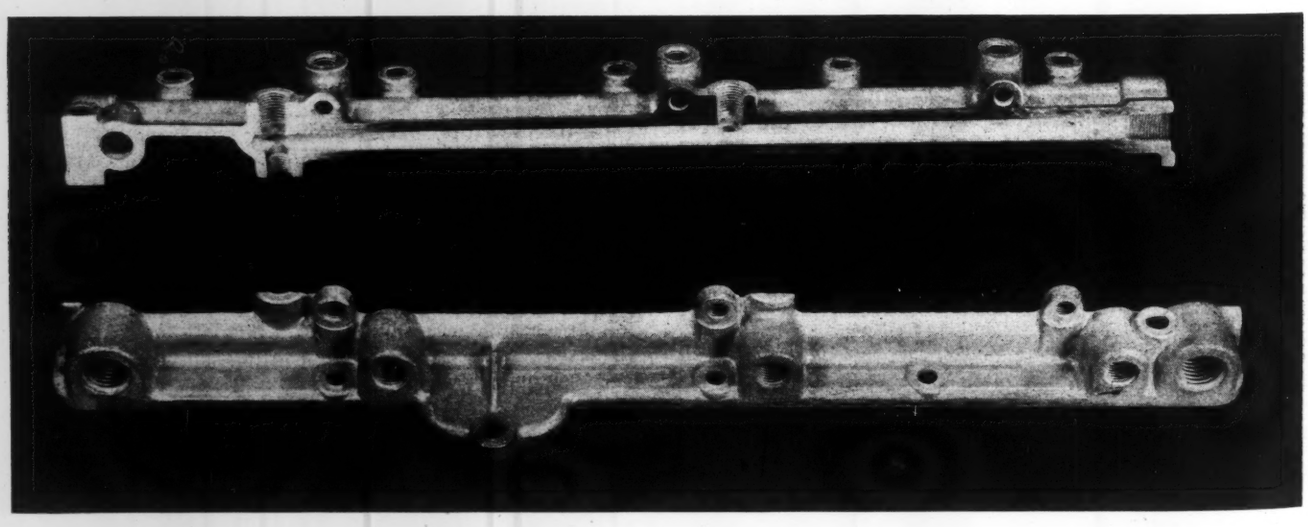
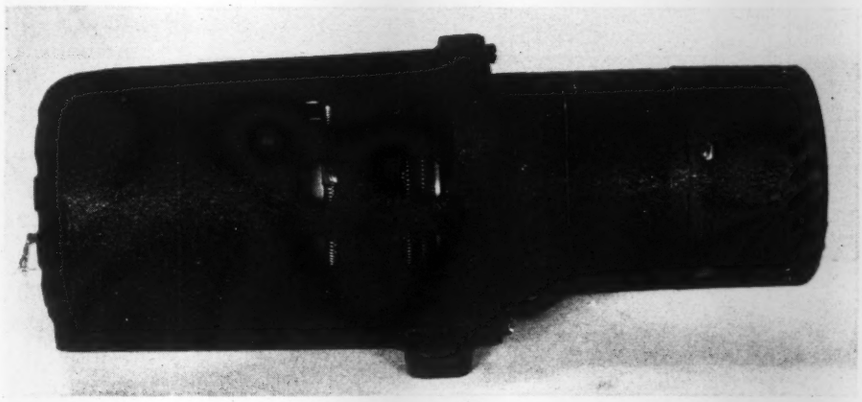


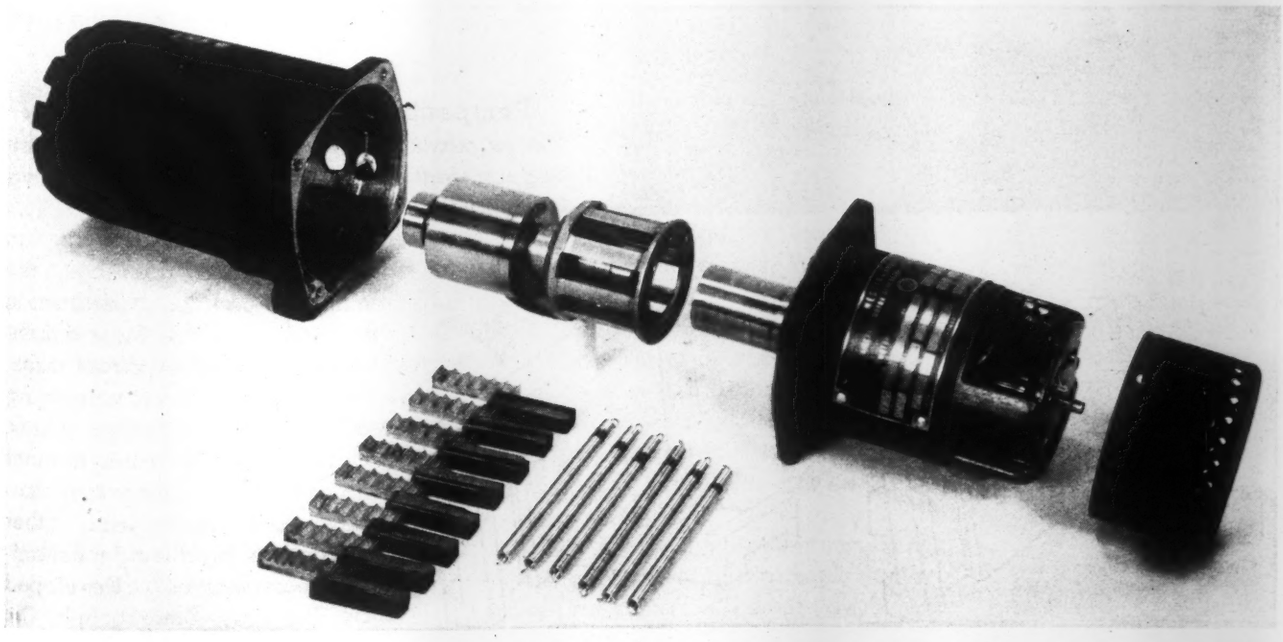
Fig. 5—Die-cast manifold. Upper view is section through cored hole 0.219-0.299-in. diameter by 10¾-in. long

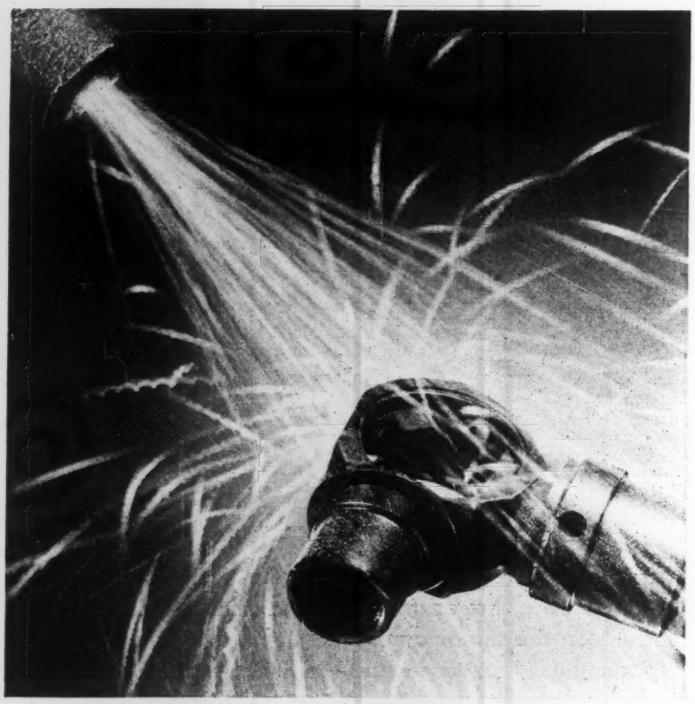
Scanning THE FIELD for Ideas

CONSTANT speed regardless of normal changes in load, voltage and temperature has been developed by Westinghouse for direct-current motors. This ingenious device, shown assembled and in the exploded view below, employs a smooth drum mounted on the motor shaft extension. Surrounding this drum is a cage with lengthwise slots. Resting in these slots and riding on the drum are carbon blocks held in position by garter springs. The cage is connected to the driven load and the motor is arranged so that at all times its speed is above that desired. Blocks and springs are adjusted so that at the correct rotation the centrifugal forces lighten the pressure of the springs and the carbons slip the right amount on the motor cylinder.

Resulting speed regulation is remarkably constant

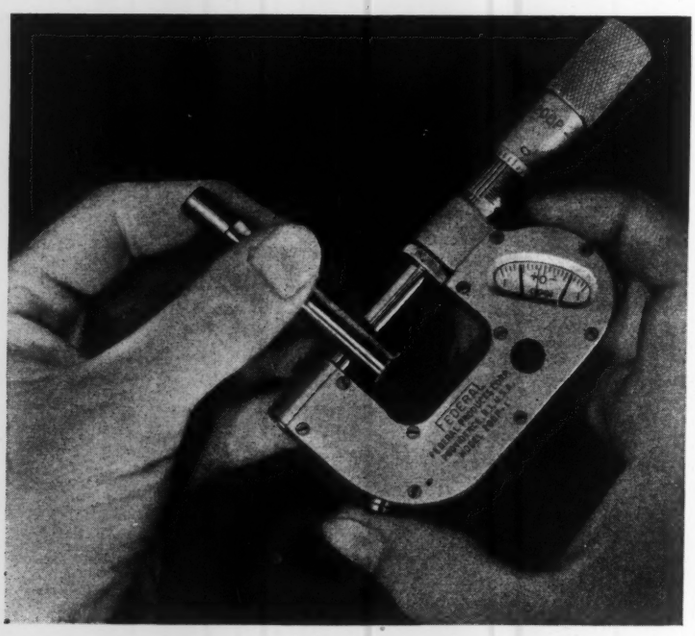






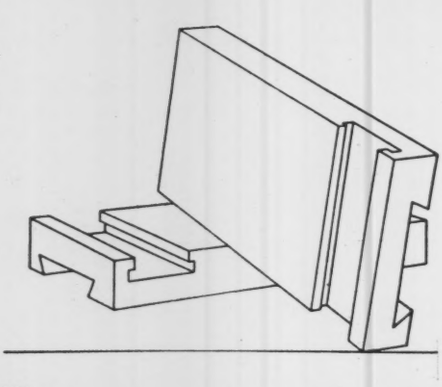
and at contant load, variation for all atmospheric conditions of the temperature, altitude and humidity is approximately one quarter of one per cent. The device is flat-compensated for wear but tests show barely measurable change in the surface of the friction members in 2000 hours of operation. Not intended for use with large outputs nor for wide load variations, a 50 per cent change in load produces a speed change of a little more than one per cent.

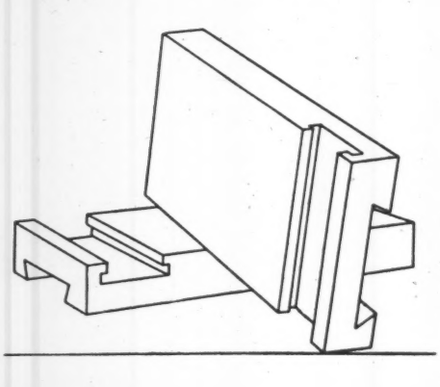
Plastic pellets are utilized to blast oxide surface smut from sand-cast aluminum-alloy parts for an optical instrument as shown at left. Blown from an ordinary blasting machine, the pellets remove minute particles of dust which are given up through the pores and which would otherwise interfere with accurate functioning of the instrument. This method of cleaning seems to draw out the dust rather than pound it in, imparts a satiny finish and is quicker and more economical than methods previously used. Pellets employed are Tenite but are slightly smaller than those used by the plastic molding industry.



Precision of a dial indicator is combined with the accuracy of a micrometer to provide an instrument free of "feel." Shown at left this micrometer can also be used as a dial comparator without the necessity of setting to a master, the micrometer feature furnishing the setting. Constant anvil pressure is obtainable for each reading, regardless of the operator.

Perspective drawings like those shown below may be drawn to scale by simply selecting sufficient points with the aid of a perspective drafting machine.

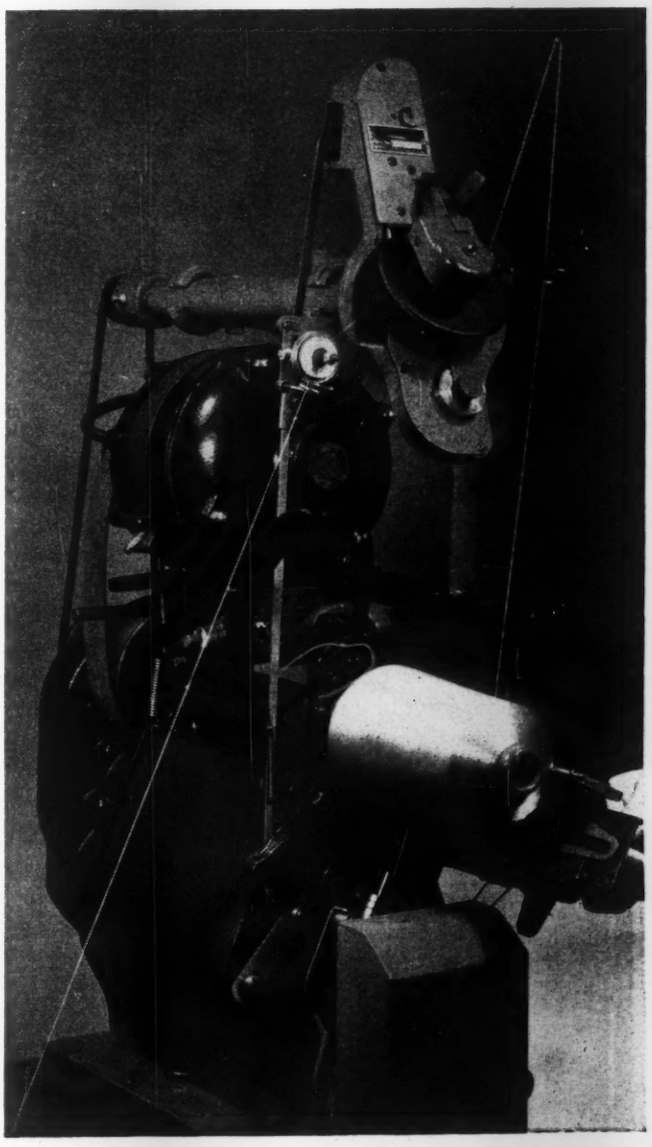




Utilizing orthographic plan and elevation drawings, the machine enables a draftsman to produce a true three-dimensional drawing by direct transfer of points without employing cumbersome vanishing points. Drawings made in this manner do not have the distortions usually associated with other methods of producing mechanical perspectives. Developed by Pomeroy Stereograph Co.

Inc., the drafting machine is mounted between two drawing boards and has a hair-line point finder and a straightedge for producing the drawing. Curves are transferred by selecting sufficient points for connecting.

The mechanism moves the hair line in a predetermined arc over the plan and elevation drawings from which the points are to be transferred. Desired viewing angle for the perspective is obtained by adjusting a calibrated slide. By shifting the viewpoint to the correct interpupillary distance, pairs may be drawn for viewing in stereoscopic relief.



Constant tension drive shown at right has been developed for winding yarns when tension and package density are important. The upper assembly of the unit, designed by Walter Kidde & Co. Inc., feeds the yarn to the package being wound. Tension is entirely independent of the supply package and is achieved by the setting of a spring. Regardless of the yarn speed, tension remains constant within reasonable limits as the package is wound. This is accomplished by a simple leverage arrangement working against the spring in which the control-arm at the top of the mechanism moves the yarn guide bar to change the position in which the yarn is run through the feed wheels. As tension tends to increase, the guide bar moves the thread away from the center of the feed wheels to where the peripheral speed is greater until the predetermined tension is achieved. When tension tends to be too light, the opposite happens. The feed wheels are positively driven and there is a throw-out mechanism for use in threading the machine as well as a simple disk tension to control the yarn as it is fed into the feed wheels. Should the yarn break, the control arm hits the wire near the extreme top of the mechanism, actuating the regular machine stop motion.

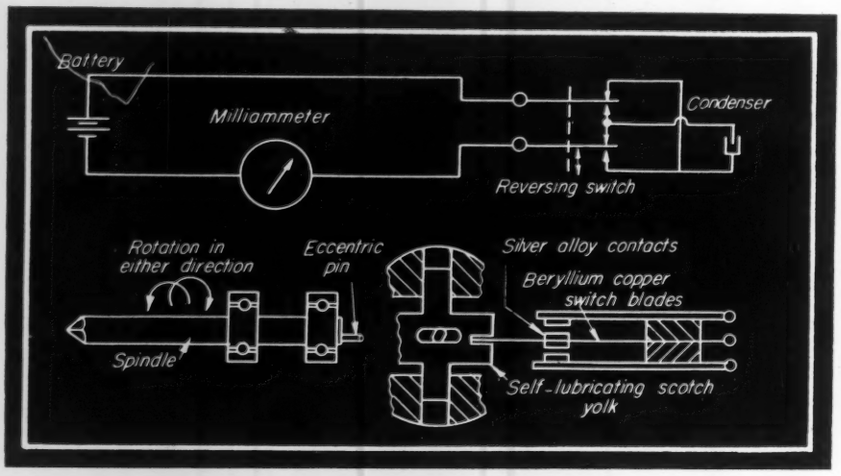
Mounted below the package the density-control mechanism is essentially an escape arrangement whereby, as pressure on the package tends to increase, the pressure bar is permitted to fall away from the package slightly through an escapement. Pressure is governed by small weights operating against the friction on the pressure bar. As friction increases on the bar it turns slightly, releasing a ratchet which permits the clock mechanism to run, relieving pressure.

Needle spark gap confined in a space containing gas at a definite pressure is used for switching in the TR box shown at right. Used in radar this electronic switch is capable of switching in less than one-millionth second at the rate of a thousand times each second. Each switching pulse is interrupted for a thousandth second to allow the radar echo to be received. When a pulse is sent from the transmitter the relatively high voltage causes the gap to spill over, short circuiting the receiver. When the pulse stops, the low-pressure gas space deionizes in about four millionths of a second and the receiver is again ready for any return signal. The device is her-

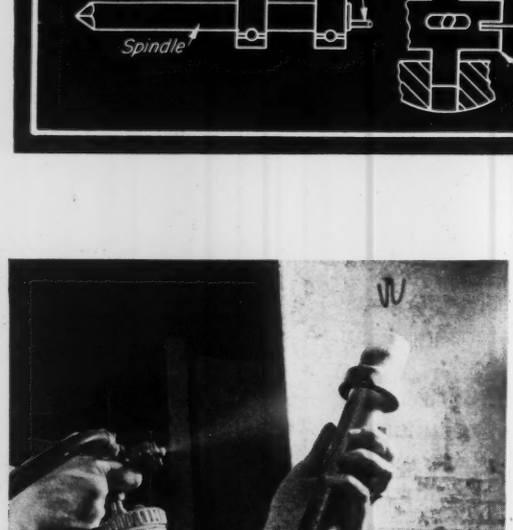
metically sealed, eliminating variations in discharge caused by air pressure or humidity. To insure that a few ions will be present when needed a separate discharge is maintained within the tube. So that operation will not become faulty in service because of gas absorption, a relatively large gas reservoir is used. This also acts as the necessary high-voltage insulator.

Small reversing switch of the positive cam acting type is utilized in the battery-operated tachometer at right. The compact head has an eccentric pin on the spindle as shown in the sketch. This pin oscillates a scotch yoke for reversing the double-pole, double-throw switch. Wear is not a factor in this design because operation depends only on the frequency of switch reversals. Motion produced by the cam is approximately 1/16-inch and the mechanism is self lubricating, minimizing wear on these parts.

When the spindle rotates, the switch blades oscillate, reversing the polarity connection of a condenser twice in each revolution. This permits current to flow from the battery through a milliameter in small charges. Thus the meter current is directly proportional to the charges or revolutions per minute. The circuit diagram is shown at left and the values are chosen so that accuracy is not dependent on time of contact dwell or on contact resistance.



Power is obtained from a small flashlight cell contained in the handle of the indicating unit. Current is zero when the spindle is not rotating and is less than 0.001-ampere when rotating, making battery life two or three years.



Powder-glass coating on Kovar for making metal to glass seals has been found to control the amount of oxidation required for a gas-tight joint, allowing the use of less experienced help for assembly. Also this new method facilitates making a seal in applications where control of oxidation has been difficult in the past.

Kovar first has its surface correctly oxidized in an oven. In this condition it is sprayed with powder glass suspended in a liquid. The piece is again heated to fuse the glass, coating the controlled oxidized film. Glass seals may then be made to this fused glass, requiring only simple skill. The method is especially suited to making large and complex seals.

Design of Supersensitive Balancing Equipment

By Karl F. Frank
Sperry Gyroscope Co. Inc.

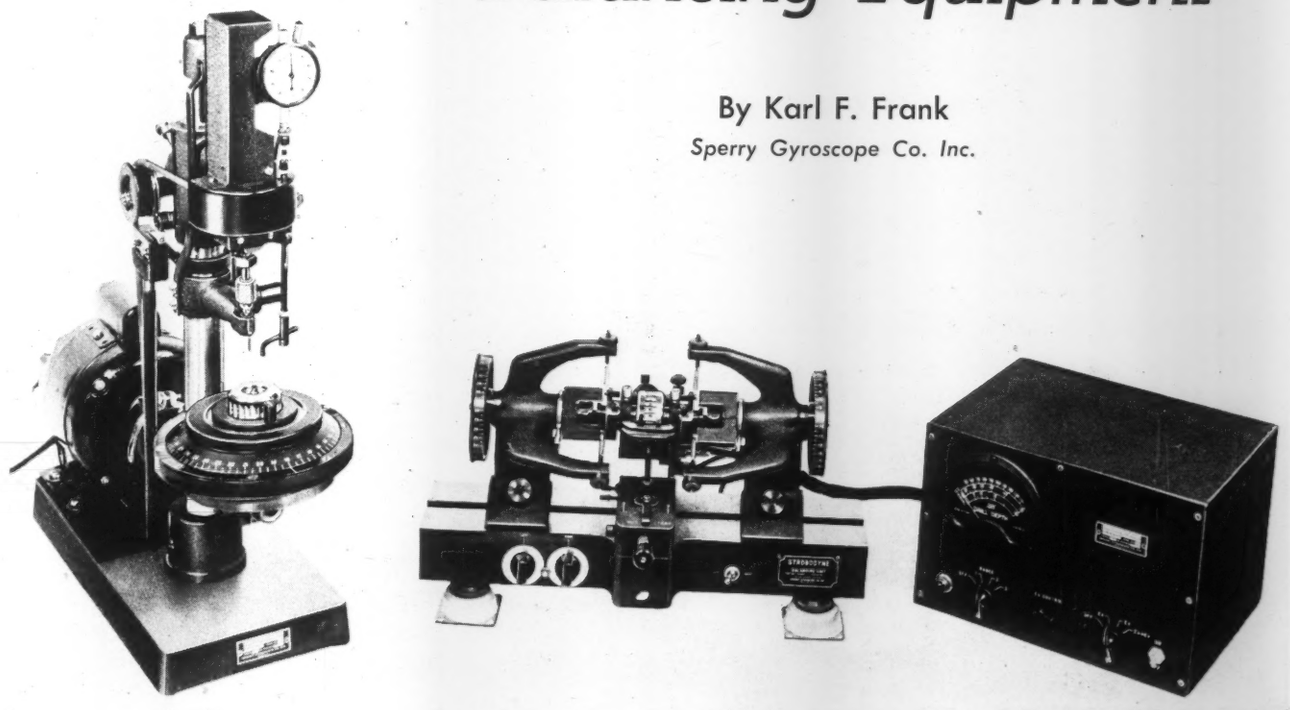


Fig. 1—Three units comprising balancing equipment are, from left to right, drilling, balancing and amplifying

IN RECENT years literature has covered the art of dynamically balancing rotating parts, and excellent machines are available for such balancing. There is, however, a distinction between ordinary requirements and precision balancing of small high-speed rotors operating at speeds from 3,000 to 100,000 rpm, where in some instances unbalance moments of 0.000,002 (two millionths) ounce-inch must be detected. It is well known that the dynamic loads on bearings arising from unbalance at high speed are relatively great and wear is appreciable. It is therefore essential that the best possible precision be obtained in balancing high-speed rotors to increase bearing life and, in the case of gyro rotors, also to remove all torsional vibration which causes disturbing gyro nutation.

Hand balancing of high-speed rotors is a slow and tedious operation requiring considerable skill. It is accomplished by placing small amounts of putty on the sides of the rotor and shifting the position and size by trial and error until the spinning rotor feels smooth. Then the rotor is drilled in accordance with the position and amount of putty present. This method breaks down entirely when balancing rotors with imperfect bearings or pivots, since vibration caused by these imperfections are mistaken for rotor unbalance, and much valuable time and effort are wasted. Hand balancing is also difficult or practically impossible when balancing rotors that have bearings with high noise level, because the sense of feel cannot discriminate against bearing vibration.

Heretofore the required degree of balance has been difficult to obtain due to the lack of suitable testing equipment. Problems faced in microbalancing, which do not exist in more common balancing operations are, in order of importance:

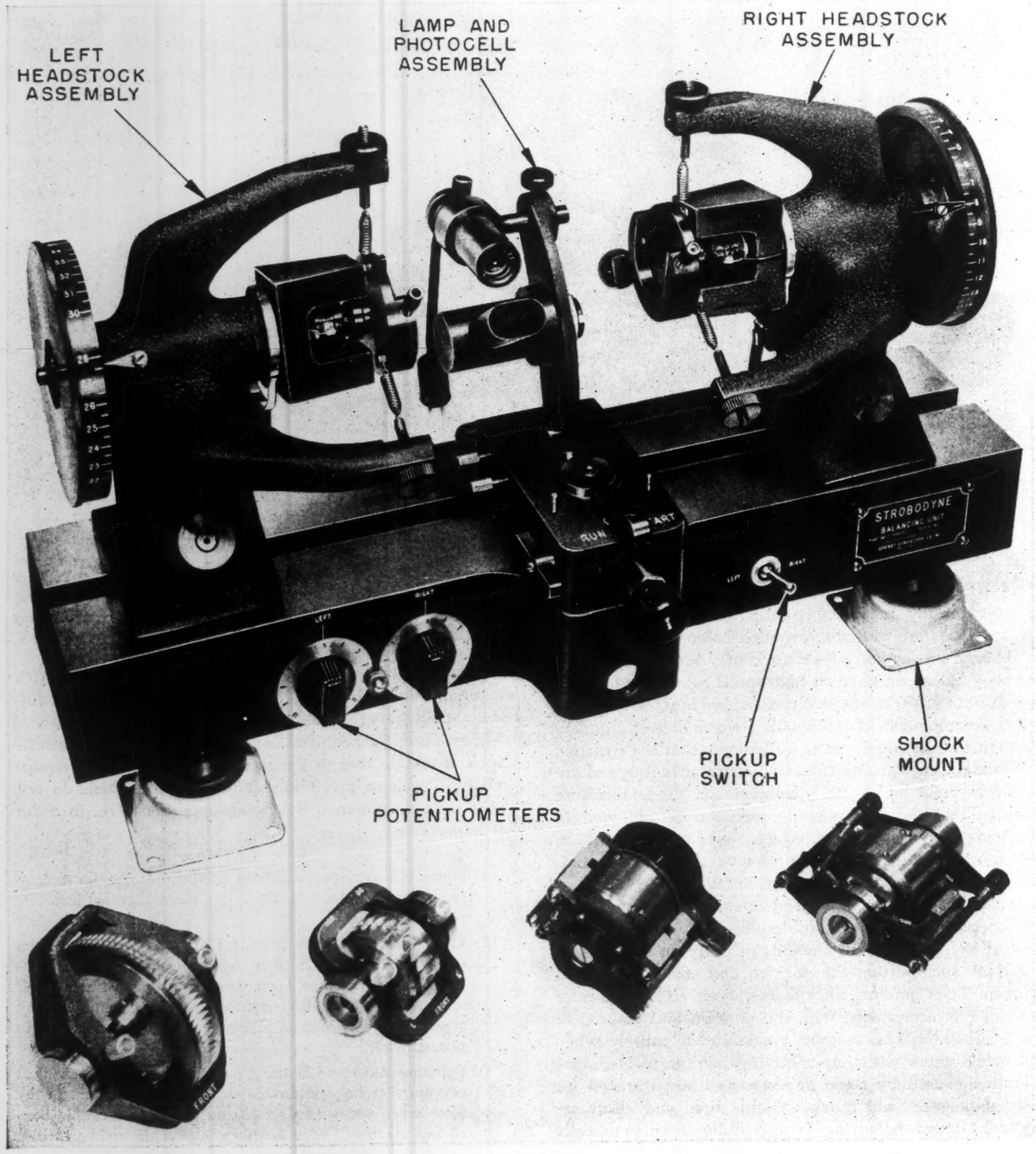
1. Obtaining extreme sensitivity of the machine for detecting vibrations of 0.000,000,2 (two ten-millionths) inch displacement.
2. Discriminating against bearing vibrations. These are often of greater magnitude than those caused by residual unbalance. A machine for microbalancing must also fulfill a secondary function of indicating bearing condition and types of defects such as elliptical races, roughness due to pits, dirt, etc.
3. Spinning the rotor in the balancing fixture. Mechanical couplings or belts introduce an unbalance moment in the rotor when removed after balancing. Under certain conditions electrical drive is either impossible or impractical;

also the signal which is to be generated for indication of rotor speed and unbalance position cannot be derived by mechanical means.

4. Mounting the bearings so that they will not be rigidly restrained in a plane perpendicular to the axis of rotor spin. This is necessary because initial unbalance would cause undue strain, and possibly ruin a rigidly held bearing.
5. Obtaining accuracy of unbalance magnitude indication in units of drill depth, regardless of the character of the unbalance, static or dynamic.
6. Providing means for removing accurately the minute unbalances from the rotor.

In view of the foregoing, it becomes apparent that special equipment is necessary to meet fully the requirements. During the development of this equipment which is shown in *Fig.* 1, the important design considerations were: Choice of vibration pickup, rotor suspension, system of indicating unbalance position, filtering the vibration signal, means for driving the rotor, and unbalance removal

Fig. 2—Balancing unit on which electrical impulses for determining magnitude and position of unbalance are generated. At bottom, left, are air-driven gyro rotors and, right, electric gyro rotors mounted in balancing cradles



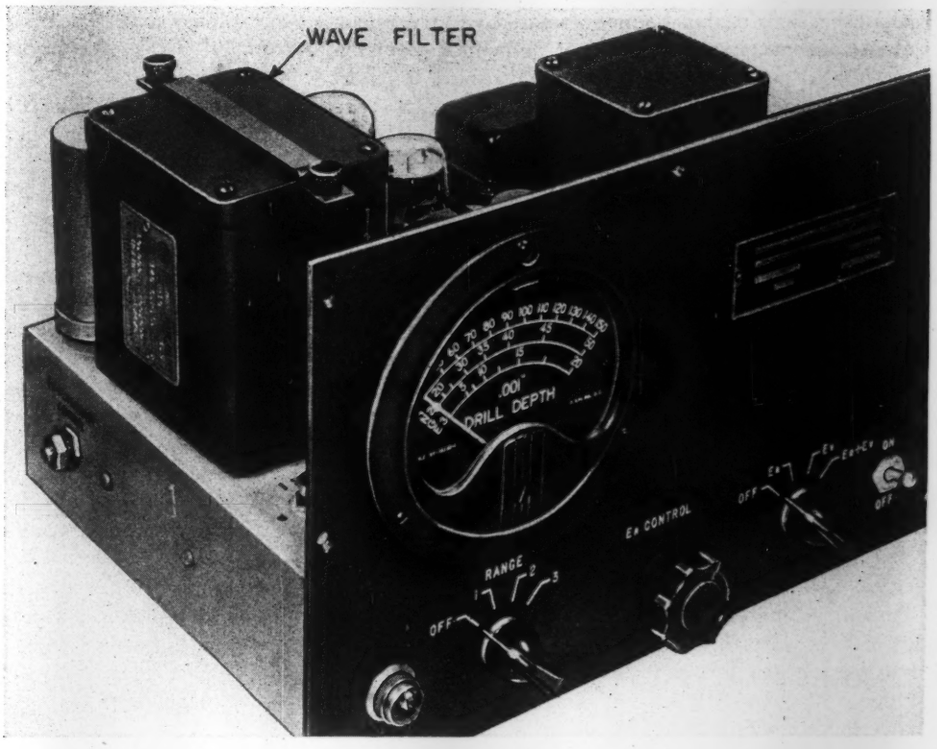


Fig. 3—Amplifying unit in which unbalance signals are mixed, filtered, amplified and indicated on a meter

equipment that will not require any computation on the part of the operator. The machine must also be adaptable to the various manufacturers' types and sizes of rotors.

As regards the pickup, it must be loosely coupled to the rotor cradle so that the low resonance of the cradle suspension is not affected and no damping due to the coupling introduced. Further, lost motion between the rotor shaft and the pickup cannot be tolerated. This is because vibration of less than one-millionth of an inch displacement must be detected. Also, the pickup should be capable of measuring the vibration in any direction in a plane perpendicular to the axis of spin. An unbalance will move a freely suspended rotor cradle in a circular path. The unbalance signal, therefore, should be of constant amplitude as the pickup is rotated through 360 degrees. However, when the slightest out-of-round bearings are used or the retainer or collet that holds the bearing introduces distortion in the race, the vibrating motion will follow an elliptical path and the maximum and minimum signal of the pickup will indicate the major and minor axes, respectively, of this ellipse.

Low Resonant Frequency Required

It is desirable to have the rotor suspended so that the axis of spin coincides with the principal axis of inertia. This necessitates a low resonant frequency of the cradle suspension. The rotor cradle should be light and sufficiently rigid to hold the bearings in proper alignment. In precision balancing, a rotor must be balanced with the bearings on which it is to operate. Any shifting of the race which is fixed to and rotates with the rotor, in respect to the rotor, usually introduces an unbalance, since even

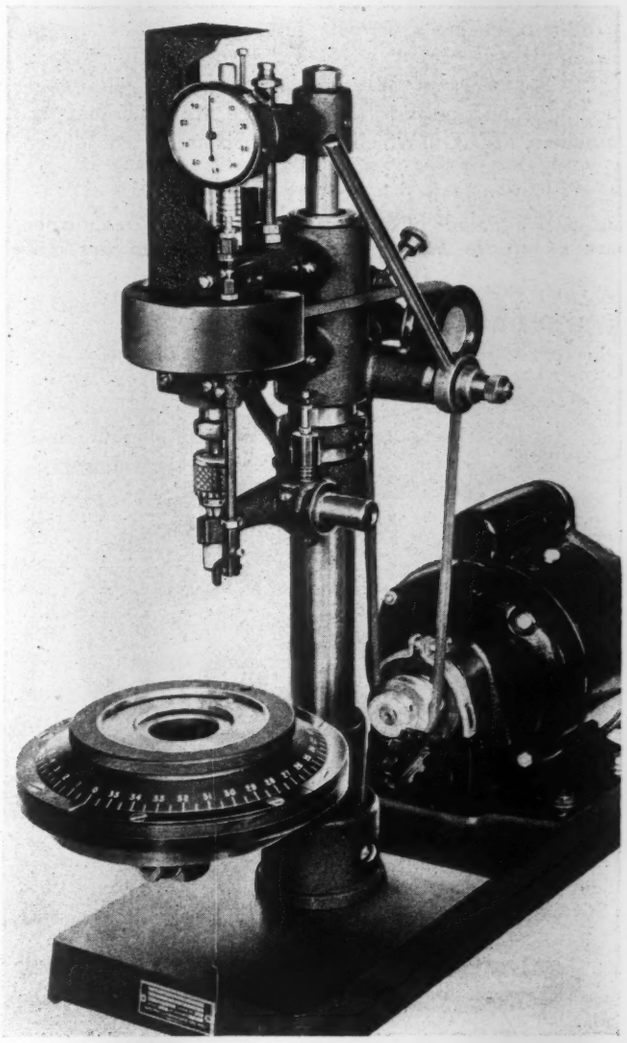


Fig 4—Right—This unit, calibrated to settings on balancing uni , removes unbalance with special drills

precision bearings cannot be manufactured with sufficiently close concentricity between inner and outer diameters of races. No portion of the cradle or suspension must be resonant to frequencies generated by unbalance or bearing vibration.

The unbalance location device must give a definite reading of position with unbalance vibrations of lower magnitudes than those caused by bearings. This necessitates the use of a filter that will discriminate against bearing vibration. As has been indicated, mechanical couplings or belts cannot be used to drive the rotor because they introduce unbalance when removed from the rotor. However, compressed air projected against the rotor can be used. To drive smooth periphery rotors, an air jet is used and the air stream is projected tangentially to the periphery of the rotor and, by means of a shroud, kept against the rotor surface. The viscous drag of the air on the rotor periphery drives the rotor effectively.

Unbalance Indicating Method Must Be Simple

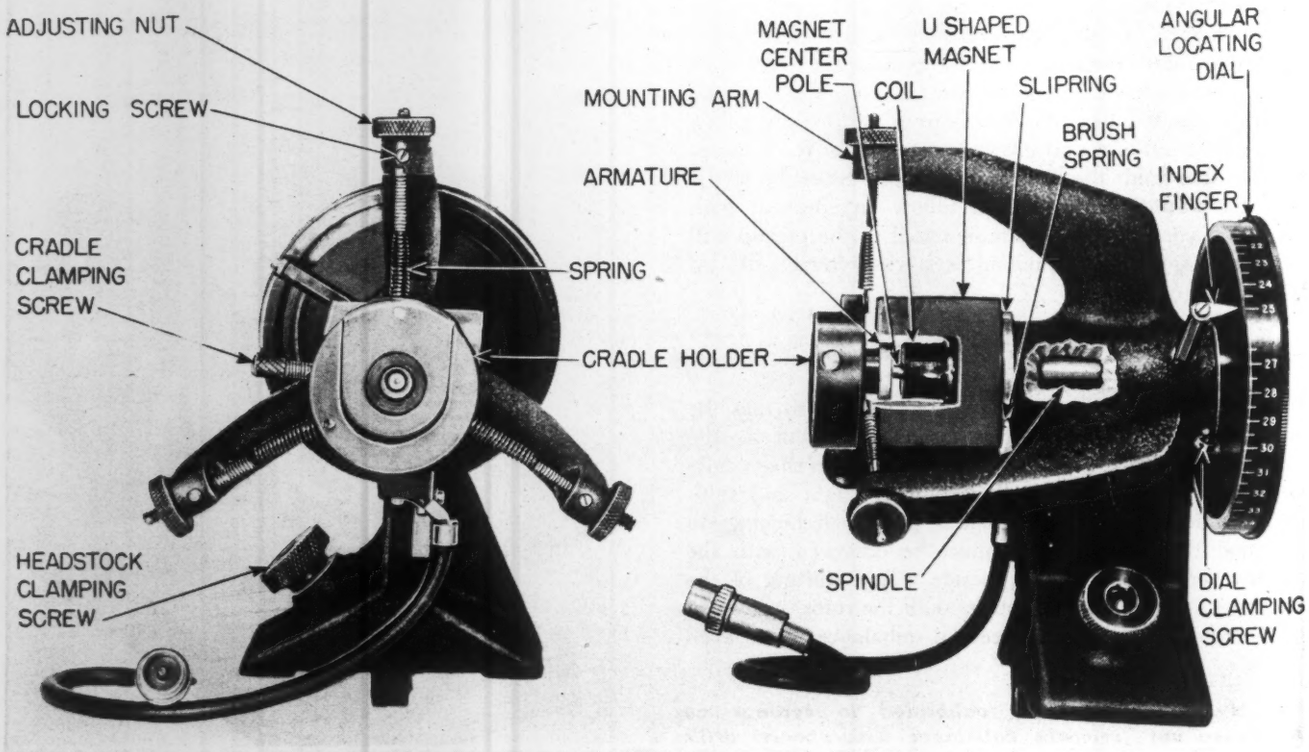
To remove indicated unbalance accurately and quickly with little or no computations on the part of the operator it becomes necessary to develop a system in which the unbalance can be read directly in units such as drill depths at a certain angular position on the rotor. It is also necessary to design equipment to facilitate the removal of the indicated amount of metal at the proper location.

In the balancing equipment herein discussed, three units are employed, namely: The balancing unit, *Fig.* 2, on which the necessary electrical impulses for determining magnitude and position of unbalance are generated; the amplifiers, *Fig.* 3, in which these signals are mixed, filtered, amplified and indicated on a meter; and a drilling unit, *Fig.* 4, where the unbalances indicated can be removed accurately.

The balancing unit is composed of a shock-mounted bed plate on which two headstocks, a photoelectric cell and exciter-lamp assembly, and an air nozzle valve block are mounted. These are adjustable to accommodate various size rotors. The upper part of the headstock assembly, *Fig.* 5, is composed of three arms, symmetrically spaced 120 degrees apart, protruding longitudinally and toward the vertically projected center of the bed plate. These arms support a cradle holder of nonmagnetic material containing a soft-iron armature. The holder is hung from the three arms on helical springs, giving the suspended system a very low resonant period. This comprises the free suspension of the rotor to be balanced. The main body of the headstock is bored horizontally to receive a spindle assembly, and the outside end of this assembly supports an angular locating dial, graduated in increments of five degrees to serve as the unbalance position indicator. At the other end of the spindle is mounted the electromagnetic vibration pickup unit which utilizes a U-shaped permanent magnet.

Within the center space of this magnet between the two poles is placed a soft-iron center pole on which is wound the pickup coil. The soft-iron ring armature, which is fixed in the cradle holder, is positioned so that the soft-iron center pole of the vibration pickup unit extends through the center of the ring armature. The hole diameter of the ring armature is sufficiently large so that the center pole of the pickup never comes into mechanical contact when the armature oscillates under the influence of rotor unbalance about the center pole. Mounted on the inner end of the spindle, next to the magnet, is a slip ring, placed over an insulator and electrically connected to the

Fig. 5—Headstock of balancing unit showing free suspension of cradle holder and vibration pickup assembly



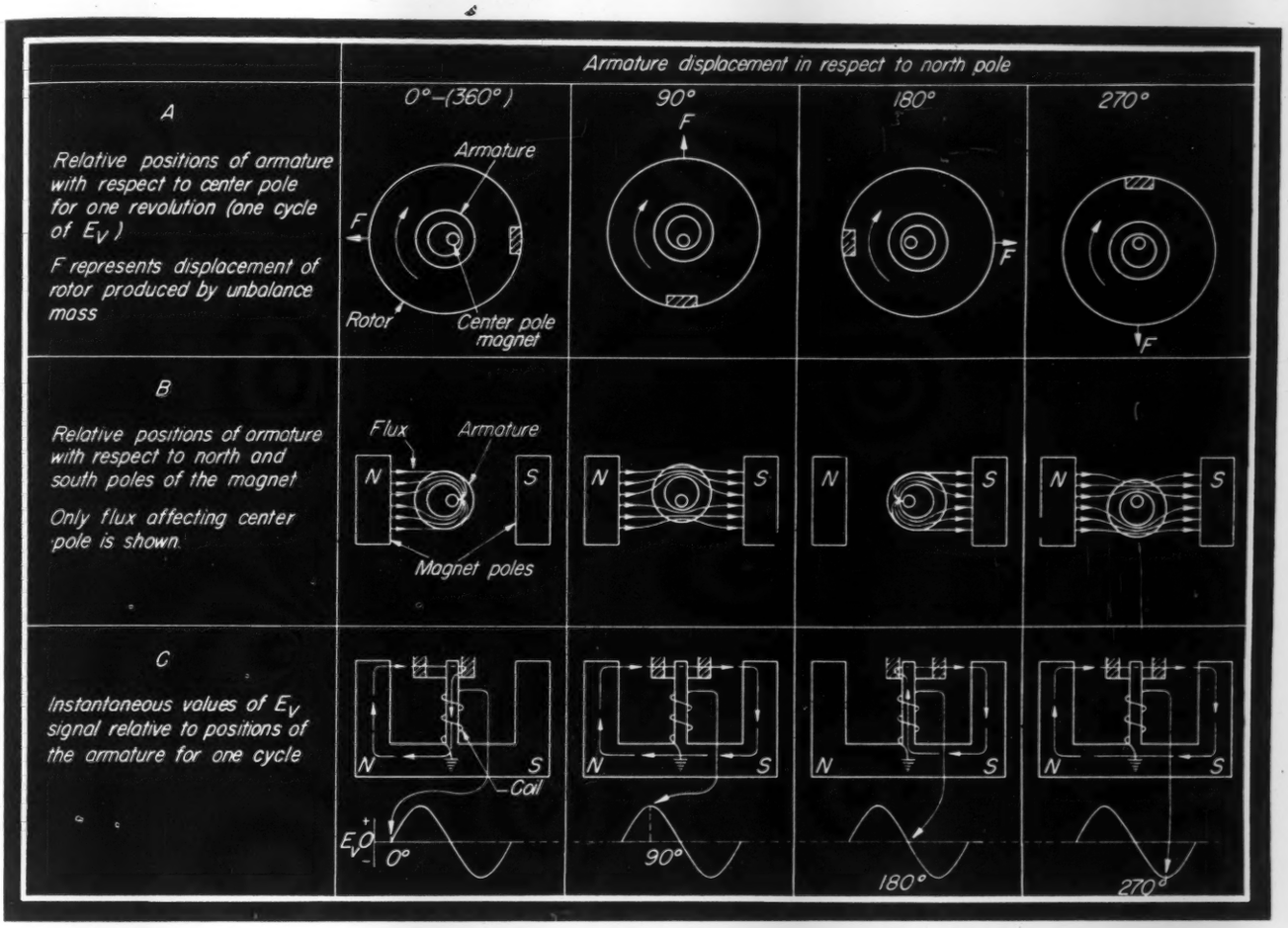


Fig. 6—Schematic representation of unbalanced rotor and armature displacement showing resulting magnetic flux in center pole and instantaneous E_v signals

pickup coil. A contact brush is attached to, but electrically insulated from the headstock, and rides on the slip ring to make continuous contact to the lead wire as the vibration pickup is rotated on the spindle. The two headstocks, one on each end of the rotor, are identical.

The electromagnetic pickup just discussed is used for converting the unbalance vibration into electrical impulses. All factors producing this voltage are constant except the displacement, which is a direct function of unbalance. The voltage generated in the vibration pickup is therefore directly proportional to the magnitude of unbalance, and the frequency of this voltage is equal to the rotational frequency of the rotor. Position of the unbalance mass in the rotor is determined in relation to an arbitrarily predetermined point on the rotor to be tested. This point is the leading edge of a nonlight-reflecting surface covering 180 degrees of the rotor periphery, and is known as the reference mark. This contrasting surface is obtained by placing a dark stripe on light rotor or a light stripe on a dark rotor. A light is directed against the rotor periphery so that the reference mark will interrupt the reflection of this light into a photoelectric cell periodically for every revolution.

An alternating potential is generated in the photoelectric cell having a frequency corresponding to the speed of rotation and also to the frequency of the unbalance signal. The magnitude of this reference signal is manually controlled and made equal to the vibration signal. Phase relation of these two voltages, which is also the relation of unbalance position in respect to the reference mark, is then determined by adding the two voltages and rotating the vibration pickup about the axis of the rotor until they cancel each other, indicating that they are 180 degrees out of phase. Angular position of the vibration pickup, in respect to the spot of light which is projected against the rotor, then indicates the unbalance position in respect to the reference mark on the rotor. This condition holds true regardless of size or shape of rotor.

How the Pickup Works

Electrical functioning of the vibration pickup is depicted in *Fig.* 6. When an unbalanced rotor is mounted in the cradle holder and rotated at balancing speed, the armature, which is attached to the cradle holder and lies on the same axis as that of the rotor to be tested, will oscillate about the center pole of the vibration pickup. The amount of magnetic flux traveling up and down the center pole depends upon the position of the ring armature. The radius of oscillation about the center pole is proportional to the rotor unbalance, and the voltage generated in the pickup coil is proportional to the radius of oscillation. Extraneous vibrations which are due to bearing imperfections are of different frequencies than the rotor speed and are filtered out in the amplifier by an electrical filter. This type of pickup does not restrain the unbalance motion since its direct coupling to the unbalance vibration is magnetic, yet

it does not introduce lost motion. This feature is essential in microbalancing and does not interfere with the low resonant suspension of the rotor under test.

How the phase relation of vibration voltage in respect to the reference voltage can be shifted by rotating the vibration pickup with the angular locating dial is shown in *Fig.* 7.

During balancing, the cradle in which the rotor is spun (some are shown with electric and air-driven gyro rotors mounted in them in *Fig.* 2) fits in the cradle holder of the balancing unit. Spacing of the headstocks is adjusted to provide for the length of the cradle and also to have the air nozzle which drives the rotor in proper position under the rotor. Bearing sleeves in each end of the cradle are in highly accurate alignment and slidably mounted to facilitate easy insertion and removal of the rotor and also to provide for proper loading of the bearings, which has a large effect in precision balancing. These sleeves hold the bearings on which the rotor is to be balanced and are locked in place with thumb screws. With separable bearings, the same diameter ball track must be maintained in operation as is used in balancing in order to maintain the required degree of balance on the rotor. Changes in position along the axis of the inner race of the bearing of only a few thousandths of an inch have introduced relatively large changes in rotor balance.

Length of the cradle is such that the suspension spring separation may be calculated by means of the following expression:

$$S=\frac{2I(\omega_{n2}^2-\omega^2)}{lM(\omega_{n1}^2-\omega^2)}$$

Where S = distance for suspension spring separation
I = effective moment of inertia, taken about a diameter of the rotor through its mass center, due to combined mass and gyro stability
M = the suspended mass
ω = balancing speed
ω_{n1} = resonant frequency of the first mode of vibration corresponding to static unbalance which is constant for any one type of rotor
ω_{n2} = resonant frequency of the second mode of vibration corresponding to the dynamic unbalance which is constant for any one type of rotor
l = length of particular rotor.

This suspension system in combination with the rotor cradle, makes it possible to have a definite rotor cradle with each type of rotor or an adjustable cradle for various size rotors and to have the correct resultants of static and dynamic unbalance indicated.

All rotors are driven with compressed air. This arrangement provides the nonmechanical coupling to the rotor. The respective air nozzles are placed in the air block which contains the necessary mechanism for controlling the air flow. A pressure-regulating valve under

(*Continued on Page* 180)

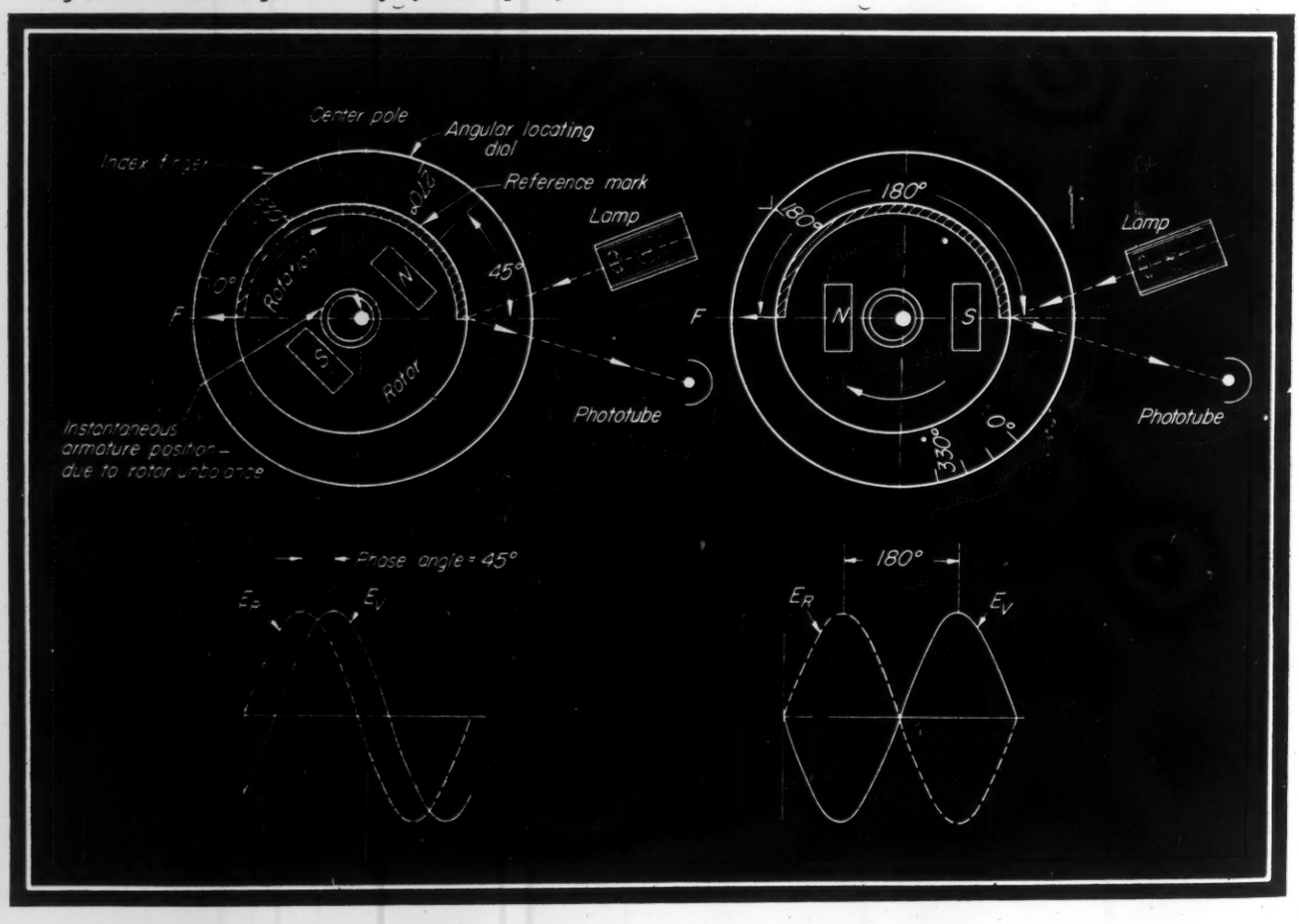


Fig. 7—Phase relation of E_r (reference) and E_v (vibration) voltage with unbalance at 180 degrees from the zero reference mark and with center line of north pole at 45 degrees and 180 degrees from projected light spot

Photoelasticity Solves a Knotty Snap-Ring Problem

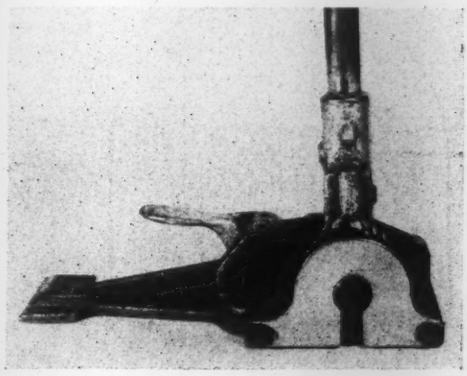
By R. E. Orton
Chief Engineer
Acme Steel Co., Chicago

Fig. 1—Above—Redesigned strapping tool. Snap ring is shown in white

APPLICATION of photoelasticity to the design of a machine element is exemplified in an interesting manner by a snap ring used to retain a shaft on the strapping tool shown in *Fig.* 1. The original design of the retainer for this shaft is shown in *Fig.* 2 and schematically in the upper part of *Fig.* 3. It consisted of a stamped plate held by cap screws to the base member. Redesign of this base member from a casting to a weldment made desirable the elimination of that part of the base to which the retainer plate was fastened. It was also felt that a better appearing and a more economical arrangement of parts could be made by the use of a snap ring instead of the retainer plate.

Because of abrasive wear it was desirable that the retainer be hardened steel and, because of the arrangement of the mating parts, it was essential to allow an appreciable projection of the ring beyond the groove in the shaft. Also, to meet interchangeability requirements for repair service, it was desired that the snap ring fit on shafts already made for the retainer plate.

F'g. 2—Below—Original design of strapping tool. Retainer plate is white



Width of Ring Increased Stress Concentration

Properly designed snap rings deform *elastically* when pressed over a groove, returning substantially to original shape after having been put in place in order to "lock" on the shaft. In this application the distance that the ring had to project from the shaft—added to the groove depth already determined—made the ring width unusually large. This, of course, made it fairly rigid with a definite limit on the elastic deformation. This would require control of the bottom diameter of the groove on the shaft to close tolerances.

Inasmuch as the original diameter did not call for close tolerances, such accuracy not being needed with the earlier design, the parts already manufactured and those in service could be expected to show a considerable variation. The only solution would be to design the snap ring with an opening smaller than the smallest expected groove diameter so that the ring would plastically deform on its first application to a par-

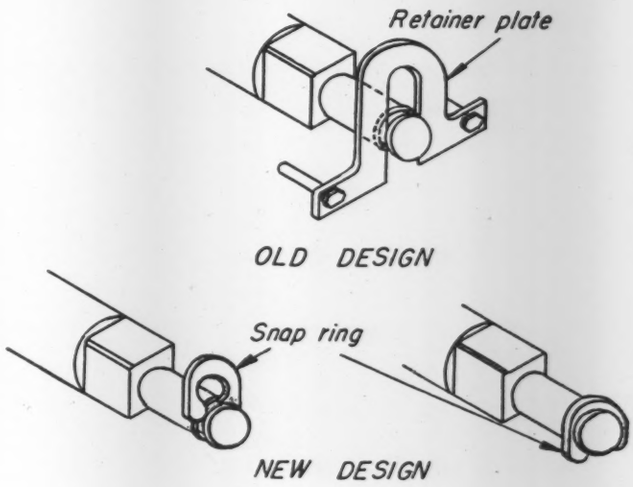


Fig. 3—Right—Old and new designs of shaft retainer plate and ring

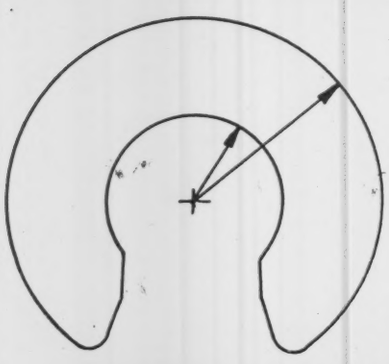


Fig. 4—Left—Preliminary contour of snap ring

Fig. 5—Above—Photoelastic fringe pattern of the snap ring shown in Fig. 4

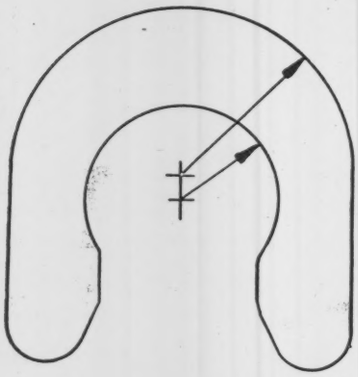
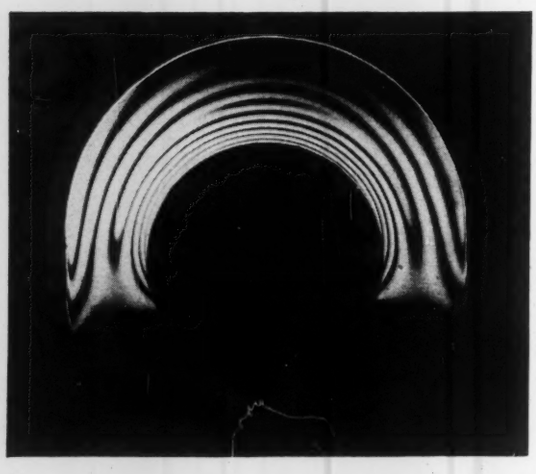


Fig. 6—Left—Final contour of snap ring

Fig. 7—Below—Photoelastic fringe pattern of ring of Fig. 5



ticular shaft, en elastically recover sufficiently to be a suitable fit to that shaft. Of course, thereafter the ring should always be associated with that shaft. The plastic deformation, too, must be such as not to destroy the elastic properties to such an extent that the ring could not be applied and removed some fifteen or twenty times on the same shaft.

Experimental rings of the first design, *Fig.* 4, failed quickly at the top of the inside edge. Photoelastic analysis was then made of this design, *Fig.* 5, with the model to the proportion of *Fig.* 4 except at the opening ends where a small hole was provided in each end. Pulling straps, passed through these holes and tensioned so as to separate the gap in the ring, provided a method of loading closely simulating the condition at the time the ring is pressed on the shaft.

Stress peak shown in *Fig.* 5 is spread over a very short distance. This means that the plastic deformation could likewise be expected to occur over a short distance, indicating an excessive plastic deformation over unit length. Failures of the experimental design that were experienced could certainly be expected from this stress distribution.

Stress Distributed by Modified Contour

Obviously, the solution to the problem was to modify the contour of the ring so as to distribute the stress peak over as large a length of the ring as possible, plastically working the largest possible amount of material so as to reduce the *unit* deformation. The model was alternately filed and checked in the polariscope until the design shown in *Fig.* 6, with the photoelastic picture of *Fig.* 7, was obtained. It should be noted that the highest stress fringe extends for at least ninety degrees around the ring, the second fringe extending for a good half circle.

This arrangement of the stress would also permit of a greater *elastic* deformation of the gap, so that the ring would be retained to the shaft in a better manner. Experimental rings manufactured to the new design proved entirely satisfactory.

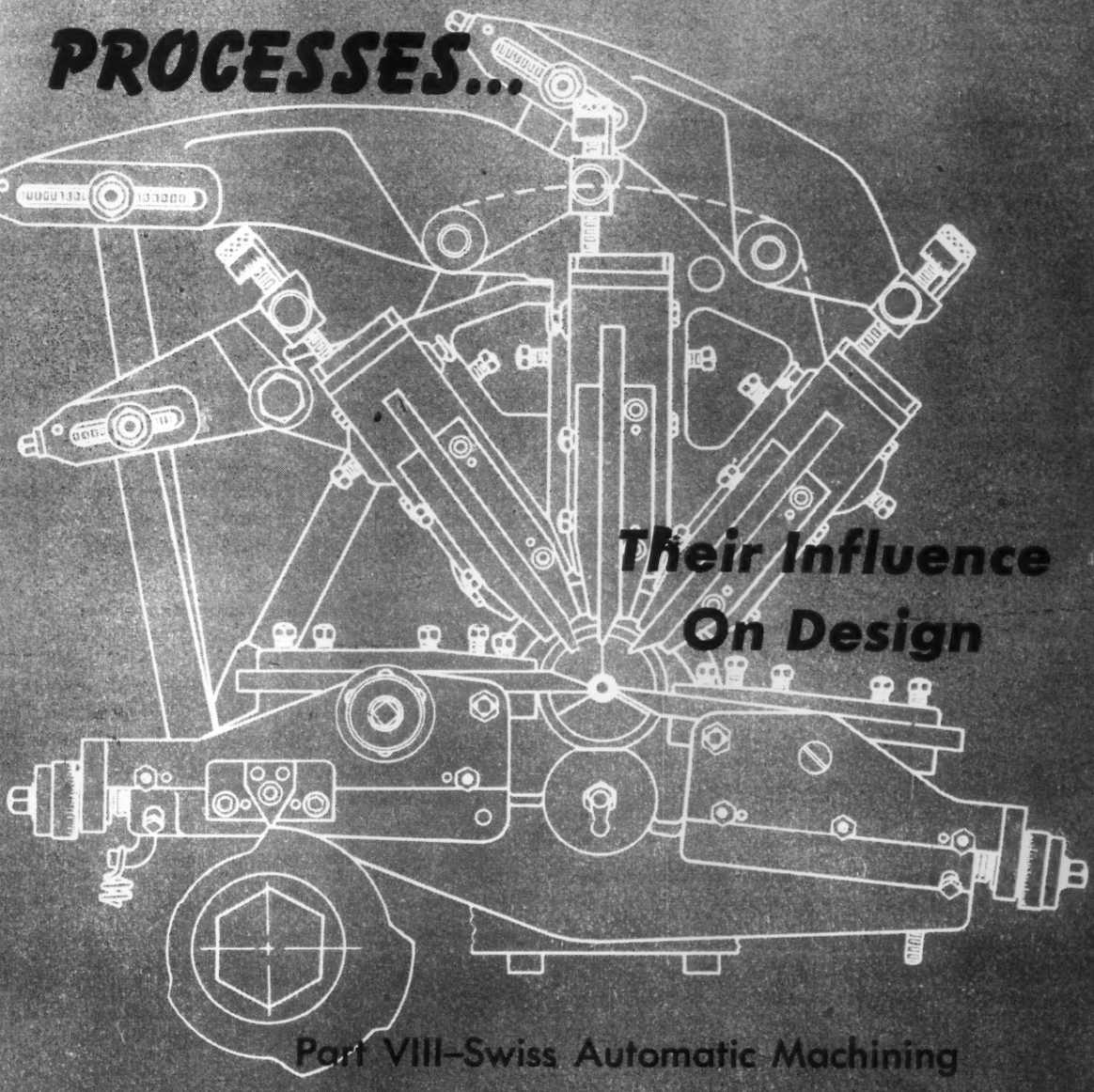
It was found advisable to control the hardness within narrow limits to permit plastic deformation without failure, and still secure an adequate elastic recovery. To attain this the parts were checked for hardness 100 per cent, drawing first on the high side of the hardness limits, segregating rings and redrawing those that exceeded the limit. Material employed was a plain medium-carbon steel, oil quenched.

Parts made to this design have proved entirely satisfactory over a period of time sufficient to disclose any errors in their design.

Annual Index

MACHINE DESIGN'S annual index of editorial contents for 1945 is available, as in previous years, on request. Indexes for earlier years also are available in limited quantities. Please address Reader's Service Dept., MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.

PRODUCTION PROCESSES...



Their Influence On Design

Part VIII—Swiss Automatic Machining

By Roger W. Bolz
Assistant Editor, Machine Design

SWISS principle of automatic machining was originally developed over fifty years ago for the clock and watch manufacturing trades in Switzerland. The American counterpart of the Swiss high-precision automatic screw machine has now become a vital and necessary part of the production picture. It is particularly well adapted to the turning of pinion blanks, studs, worm gears, indicator staffs, shafts, and other minute or slender parts used in clocks, meters, radio or electronic equipment, calculating machines, and a wide variety of industrial instruments.

The method of turning employed in these automatics which makes them ideally suited

to the production of small and slender, finely finished parts is that of feeding a revolving piece of stock through a guide bushing past radially-fed tools, *Fig.* 1. Unlike the turret-type single-spindle automatic screw machine*, only single-point turning tools and narrow form tools are utilized. The tool slides are mounted in one working plane and disposed radially from the collet centerline in the upper half of a semicircle, *Fig.* 2. Ability to produce long, slender parts to a high degree of finish, accuracy and concentricity therefore may be attributed to the fact that the cutting faces of the tools are but a few thousandths of an inch from the stock support and at no time need be farther than 1/32-inch away. Stock is fed through the guide bushing to the tools by means of a sliding headstock which grips and carries it by means of a collet feed mechanism.

Wide Range of Generation

Sliding headstock as well as the five radial tools are traversed by individual cam action. Independent cam control of each of these units obviates the need for any wide form tools since proper combination of headstock and tool movements can be had to generate pivot points, back shoulders, multiple diameters, tapers, etc. There is almost no limitation to the scope of the form generating, back shoulder and back recessing work which can be accomplished within the capacity of the machines. In fact, many parts incorporating pivot points, extensions, spherical ends, etc., can, with one automatic cycle of a machine, be completed and finished to final form in the cut-off operation, *Fig.* 3, thereby eliminating secondary machining operations and the attendant loss of close concentricity. Quality of finish and high degree of accuracy obtainable also obviate, in most cases, secondary operations such as grinding—burnishing or polishing of pivots or bearing surfaces usually being the only additional requirements.

Capacity of American machines now available ranges from 5/32-inch to 1/2-inch maximum. Four machine sizes within this range are available for production—5/32, 3/8, 7/16, and 1/2-inch maximum chuck capacities. Principal advantages of the smallest machine are higher spindle speeds and proportionally smaller working parts which permit closer running fits and consequently production of parts to the greatest possible accuracy. Minute parts, *Fig.* 4, can be handled in this machine with ease and tool settings can be made with the exactness and delicacy necessary. Parts produced on the 5/32-inch machine are limited to a maximum length of 1 9/16 inches.

With almost equal capacity for intricacy and accuracy, the largest of the machines—½-inch maximum chuck grip—can handle the greatest range of sizes. Using the standard headstock plate cam, parts up to 2 ¾ inches in length can be produced. By substituting a special bell cam, the maximum length can be increased to 4 inches. However, with the addition of a special steady rest to provide adequate support and a special stock stop to assure accurate length, parts up to 9 inches in length can be produced by double feeding the stock, *Fig.* 5.

In addition to speeding production of intricate, slender parts through virtual elimination of secondary turning and grinding often required for finish and accuracy, many additional operations may be performed by means of special attachments further enhancing the possibilities. These permit drilling, chamfering, counterboring, tapping, threading, knurling, reaming, burring, and slotting, *Fig.* 6.

Turret-Type Automatics Faster

Suited primarily to the production of parts too small, slender or intricate for completion on a turret-type automatic, the Swiss-type automatic reduces the production time and improves the accuracy compared with the usual secondary operations and precision bench-lathe work, *Fig.* 3. Whereas, on most standard single-spindle turret-type

* See Part III on designing for automatic screw machine production.

Fig. 1—Below—Stock in the Swiss automatic is rotated within and fed to the tools through a guide bushing collet

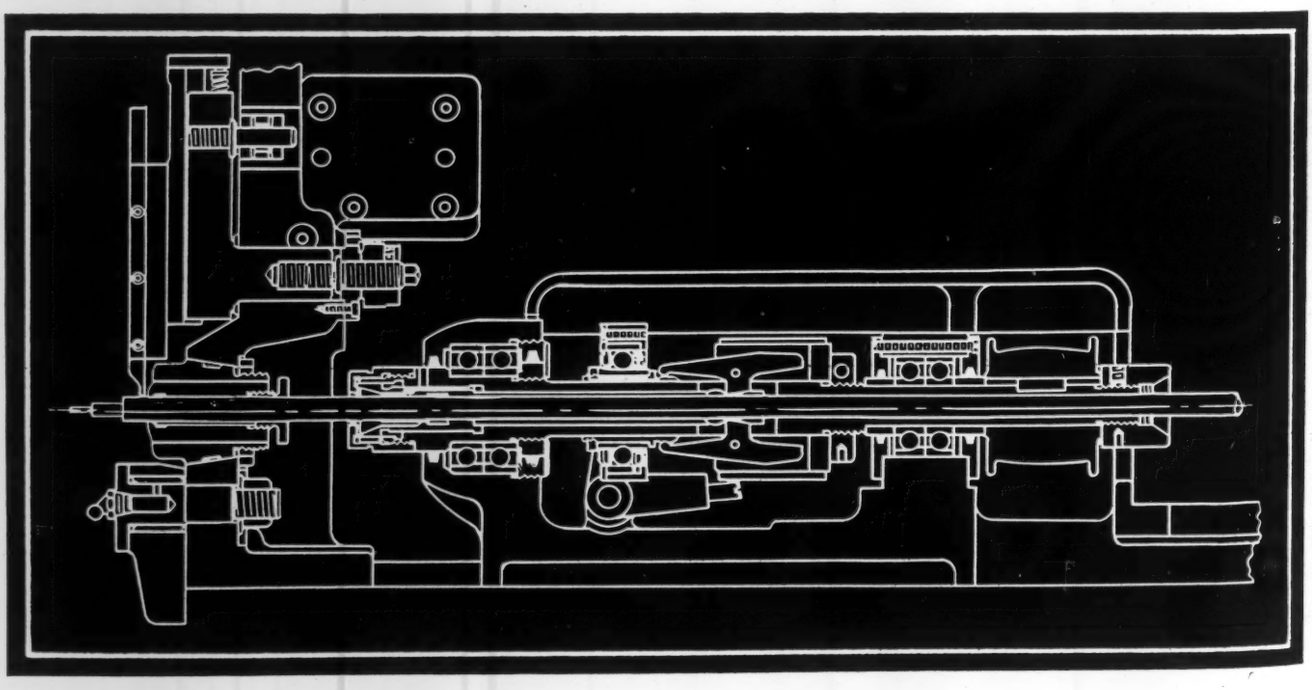
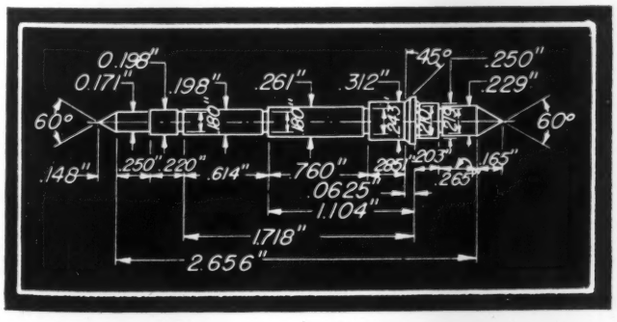


Fig. 2—Right—Tool slides are disposed radially in the upper half of a semicircle and controlled individually by cams. Opposing lower tools are fitted on a single rocker for operation by one cam visible at the left

Fig. 3 — Below — Intricate designs, of which this shaft is typical, can be produced in one cycle. Previously made in 14 separate setups, it was completed in 4 minutes, 36 seconds on the Swiss automatic at a tremendous saving in time



automatics it is common practice to turn out small screw machine parts of simple design in 5 to 15 seconds, cycle time on Swiss-type machines average about 1 minute. Depending upon the size, design intricacy, accuracy, and finish required, however, cycle times may vary from as little as 2 seconds to as much as 9 or 10 minutes per piece. Reported scrap losses as high as 50 per cent with ordinary machining conditions have been reduced to less than 10 per cent, enhancing production and reducing costs. Considerable increase in output can often be accomplished by designing parts so that as many as three or four completed pieces can be produced and cut off before the nonproductive time of retracting the headstock takes place.

Although normally most efficient and economical for large quantity production, standard cams, once developed and perfected, make it possible to simplify setup and reduce tooling costs to a point where quantities around 1000 pieces can be made at highly competitive prices.

Standard Cams Simplify Design and Production

DESIGN: Inasmuch as both the headstock and tool movements are directly controlled by cams, cam grinding must be particularly accurate. Depth stops or limits are provided only on the rocker tools, *Fig.* 2. Accurate depth or diameter control is, therefore, dependent upon cam accuracy. Slight inaccuracies in cam base diameter can be corrected by micrometer adjustments at each tool slide. Generating cams and cylindrical cam segments, though, must be accurate to reproduce proper form. Consequently, once a set of standard cams is on hand, production costs can be kept to a bare minimum by desiging all parts to the greatest possible extent around standardized dimensions and forms. One aircraft instruments plant has in this way bettered the unit cost of certain standard parts produced on the Swiss automatic over those made on small hand screw machines.

Radial tool arms, with the exception of the two bottom rocker tools, are provided with adjustment slots allowing the ratio of tool travel to cam travel to be varied from 1:1

up to 3:1, depending upon the particular type machine. Thus, standard cam motions can be modified to suit a variety of jobs within a limited range.

Standard collet capacity runs from 1/64-inch to 1/2-inch diameter in increments of 1/64-inch. Odd-size stock or special-shape cross sections require special collets. Cheaper cold-drawn stock in lieu of centerless ground stock requires a special self-adjusting type collet to accomodate the fluctuations in size and finish.

Diameters which may be produced satisfactorily run from 0.005-inch to 0.500-inch. Part lengths may run from 1/32-inch to as much as 9 inches, *Fig.* 7. As a demonstration of the turning possibilities, a pin 0.005-inch in diameter was machined to a length of one inch successfully.

An idea as to some of the wide variety of forms which are possible to generate can be gained from the parts shown in *Fig.* 8. That shown in *Fig.* 9 illustrates counterboring, back recessing, centering, and drilling operations. In *Fig.* 10 a complete layout of operational sequence and rough plan of tool usage for a typical part is shown to help visualize the possibilities of designing to utilize simple standard tooling.

Corner radii are necessarily sharp for close shoulder work and usually are on the order of 0.005 to 0.015-inch. Sharp corners or small radii can be held economically on soft materials such as brass, aluminum or "pinion stock", but where tough materials such as stainless steels are to be turned, tool grinding and setup costs are high unless carbide tools can be used. Wide allowable radii variations, of course, enable much longer production runs.

Attachments Increase Design Possibilities

Special triple-spindle drilling attachments provide for centering, drilling, counterboring, reaming, tapping, or threading. One spindle is stationary for centering and a second can be stationary or rotated left hand (opposite the stock) for drilling or reaming. Third can be stationary for drilling or reaming or turned in a right-hand (with the stock) direction for slow threading or tapping operations. Maximum diameter of drill that can be used is ¼-inch in steels and ⅜-inch in brass or other nonferrous materials. This three-spindle attachment is, of course, limited to the drilling of two diameters or to drilling one hole and tapping it. It is possible to thread one diameter with the end attachment and thread a second diameter with a thread-rolling tool from one of the radial tool slides. Deep holes up to 2 inches can be drilled by means of three or four pull-outs to clear chips.

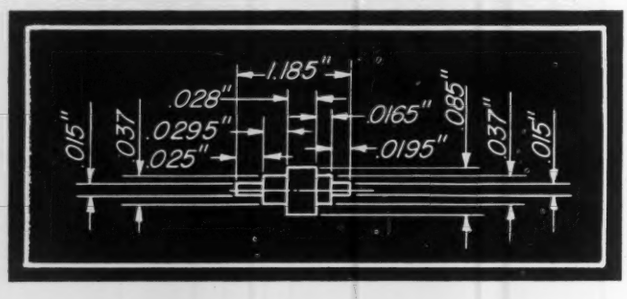
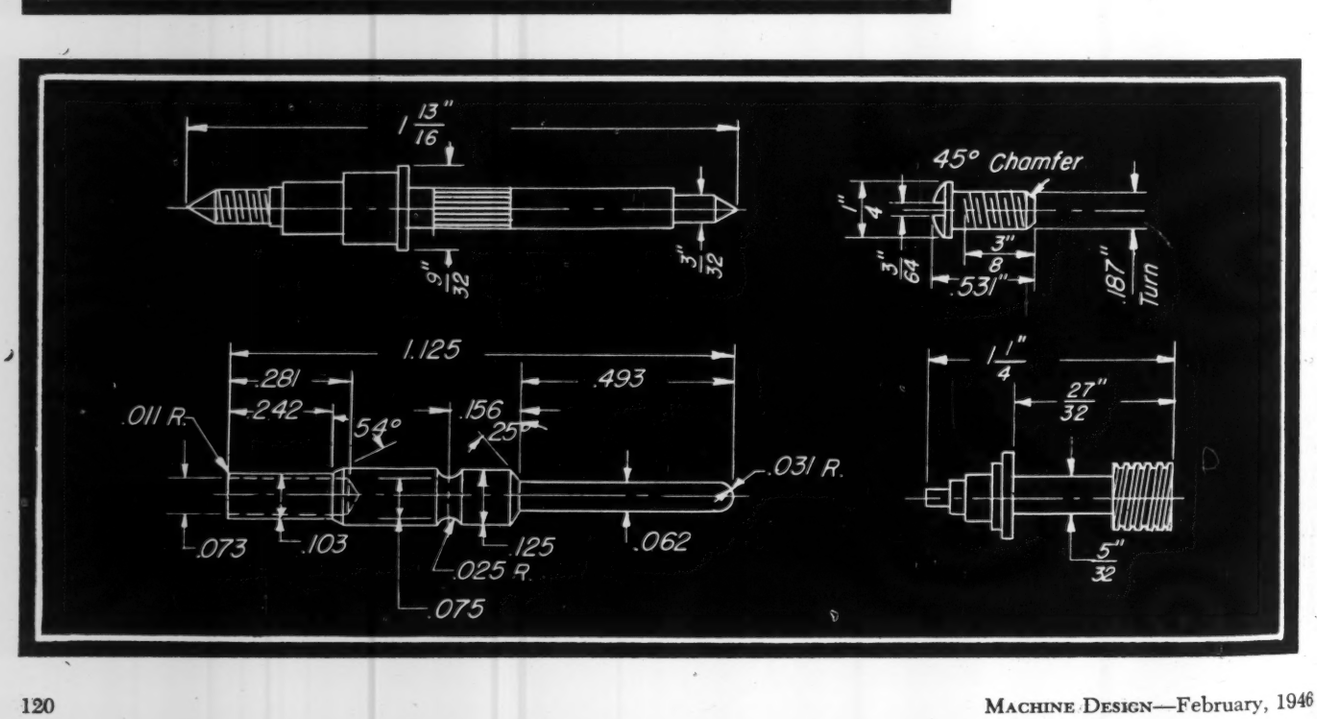


Fig. 4—Above—Minute parts are handled and finished to highly exacting tolerances on Swiss-type machines

Fig. 5—Below—Slender shafts up to 9 inches in length can be produced by double feeding the stock

Fig. 6—Below—Typical parts which include some of the additional operations performed by special tooling



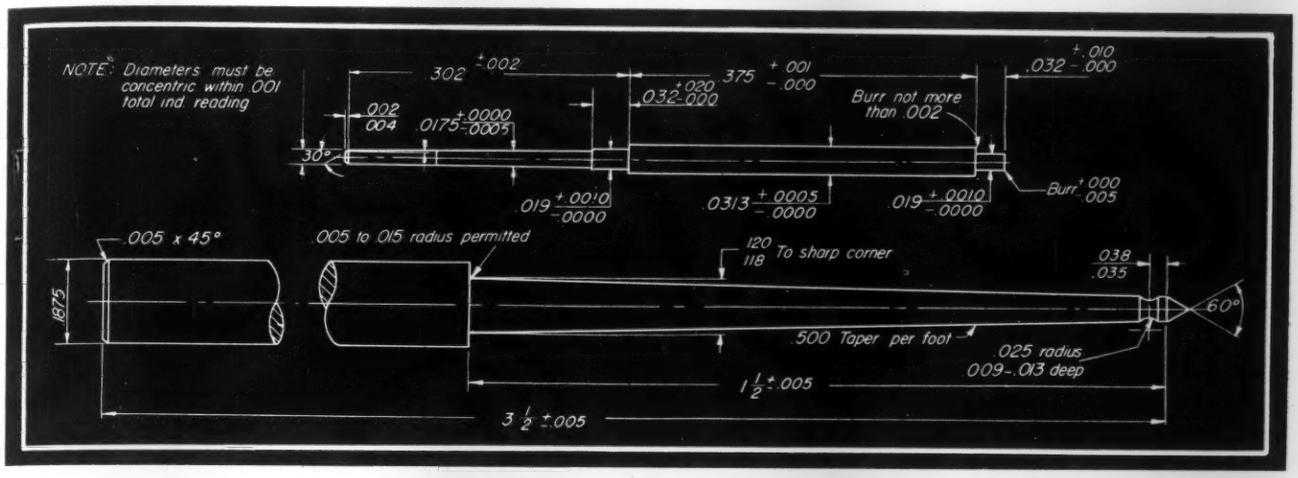


Fig. 7—Above—Owing to constant support of the stock at the tools, exceedingly small and delicate sections can be produced to fine accuracy

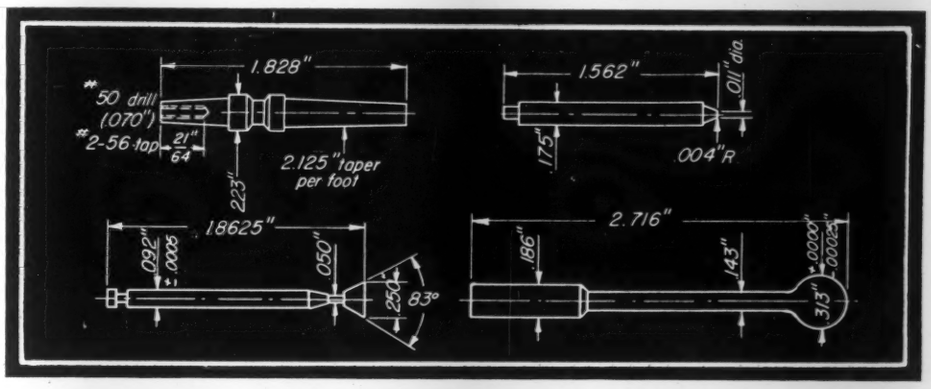


Fig. 8—Right—Typical instrument parts illustrating the wide variety of special forms which can be generated

With acorn or button dies, threads up to number 10-32 can be made in steels and up to ¼-28 in brass or other nonferrous materials. By means of a special attachment with a self-opening die head, threads in steel can be cut up to ¼-28 and up to 5/16-24 in brass. Length of threads in any case is limited to 2 inches or less.

Tapping up to number 10-32 threads can be done in steel with a 75 per cent full thread. In nonferrous materials this can be increased to 5/16-24. Maximum depth of tapping is about 2.5 times the thread diameter.

Slotting and Light Milling Possible

An attachment—with an automatic pick-off arm—which accomodates a 1.750-inch diameter slotting saw can be utilized for slotting and light milling operations without interrupting the turning cycle. Maximum length of work which can be handled with a slotting attachment varies from 1.250 to 1.500 inches, depending upon the machine.

MATERIALS: Both materials and surface speed of cutting have a direct bearing upon quality of finish and the accuracy obtained. For this reason drill rod (0.95 to 1.05C) is frequently used. Rods up to 0.125-inch in diameter are centerless ground and polished to plus or minus 0.0003-inch and those from 0.125 to 0.500-inch are ground to plus or minus 0.0005-inch. In standard lengths, small sizes of drill rod (0.013 to 0.016-inch diameters) cost about $35.00 per pound. Such material is costly but accuracy and finish obtained usually warrants its use.

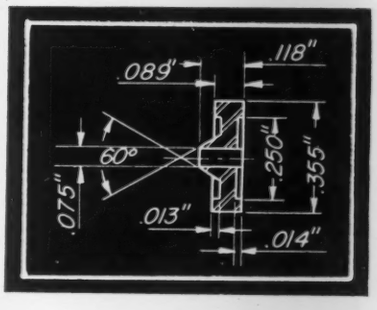


Fig. 9—Right—Back-of-shoulder recessing is easily accomplished by reversal of the headstock feed during the machining cycle

Similar both in tolerances and finish is the previously mentioned "pinion stock". This material is used widely in place of bessemer screw stock (B 1113), which has about the same physicals.

Nonferrous materials such as brass, bronze, and aluminum can also be used. As previously noted these materials as well as various high machinability steels* can be handled in the plain cold-drawn condition provided a self-adjusting collet is available and tolerances are not too exacting.

Much instrument work requires stainless-steel parts and this material, usually centerless ground to the above limits, can be handled successfully provided feeds are slower. For instance, feeds for forming cuts may range between 0.0003 and 0.0005-inch per revolution and for regular straight turning operations 0.0002 to 0.0007-inch per revolution. Feeds and speeds depend greatly upon the finish and accuracy desired. Cold-drawn ordinary steels and nonferrous stock can be machined at a much greater

* See Part III on designing for automatic screw machine production.

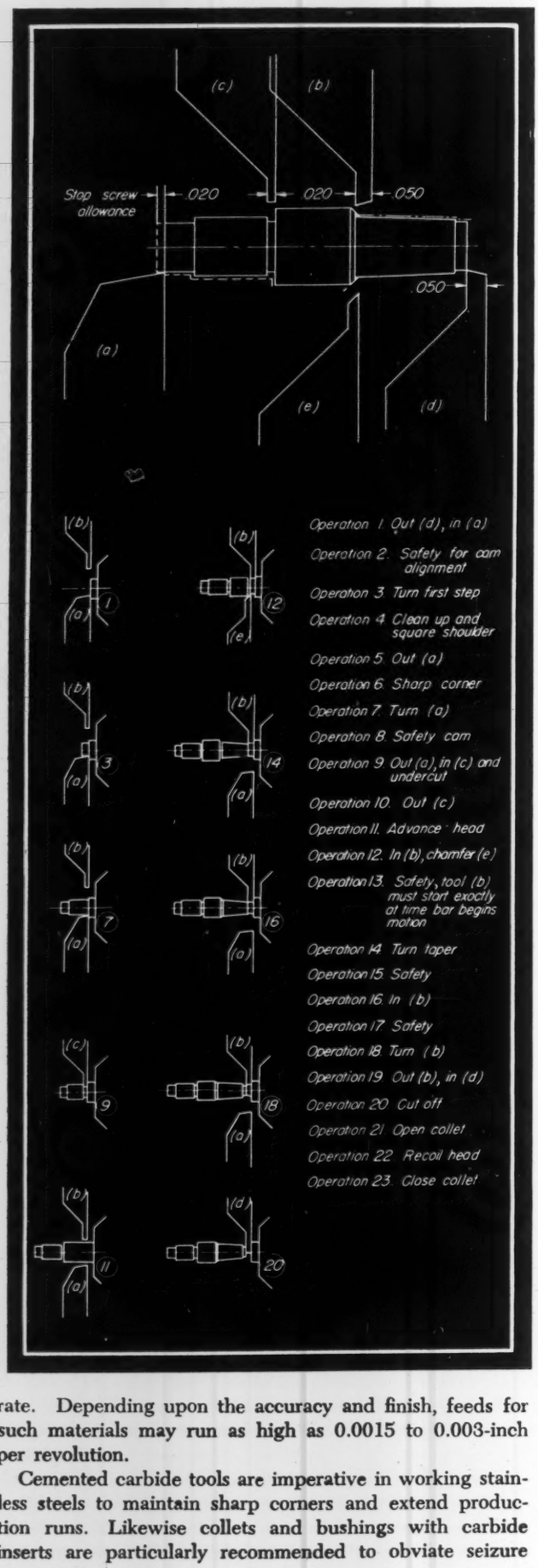


Fig. 10—Left—Details of operational sequence in machining a typical Swiss automatic part. Rough plan of individual tool usage, top, shows shape of generating tips and work accomplished by each of the five radial tools

rate. Depending upon the accuracy and finish, feeds for such materials may run as high as 0.0015 to 0.003-inch per revolution.

Cemented carbide tools are imperative in working stainless steels to maintain sharp corners and extend production runs. Likewise collets and bushings with carbide inserts are particularly recommended to obviate seizure and galling on stainless and similar types of tough or "gummy" stock.

TOLERANCES: As noted previously, size accuracy and fine finish are dependent to a large extent upon materials, feeds and cams. The accuracy of parts produced is affected directly by the accuracy of the stock and its fit in the guide bushing. Centerless-ground material, although varying slightly (plus or minus 0.0005-inch) from rod to rod, is relatively more uniform in diameter (plus or minus 0.0003-inch) throughout any one rod. This makes possible a close push fit for each bar. Guide bushing collets with carbide inserts provide for closest adjustments to centerless-ground stock without galling and thus assure maximum accuracy.

Normally, using centerless-ground stock, parts produced on the larger machines can be held to plus or minus 0.0005-inch in large-scale production without noticeable tool trouble. However, with light cuts and slow feeds to favor accuracy, tolerances of plus or minus 0.0002 to 0.0003-inch can be maintained. Certain forming cuts can be held to even closer tolerances, *Fig.* 8. The smaller machines producing minute parts, *Fig.* 4, can with favorable conditions hold limits of plus or minus 0.0002-inch or less in production.

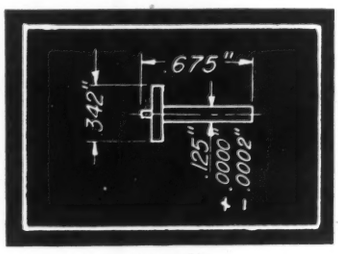


Fig. 11 — Right — Excellent finish—5 microinches on this piece—eliminates need for grinding on certain parts such as this 303 type stainless-steel pinion shaft blank

With proper feeds and speeds, surface finishes from around 50 microinches to as fine as 5 microinches can be had, *Fig.* 11. In the manufacture of instrument parts, surface accuracy of 12 to 16 microinches is reported as an average obtained in production.

Concentricity naturally is dependent mainly upon the accuracy or uniformity of the stock. With centerless-ground material and carbide-insert collets, total runout will not exceed 0.001-inch and as a rule will be considerably less. On the 5/32-inch size machine runout under these conditions will usually be less than 0.0005-inch.

These highly exacting tolerances, of course, should be limited to critical dimensions and wherever possible wider tolerances should be used to aid production. If concentricity and diameter tolerances can be somewhat greater, costs can be reduced considerably by specifying cold-drawn material.

Collaboration of the following organizations in the preparation of this article is acknowledged with appreciation:
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City Engineering Co. (*Fig.* 2) . . . . . Dayton, Ohio
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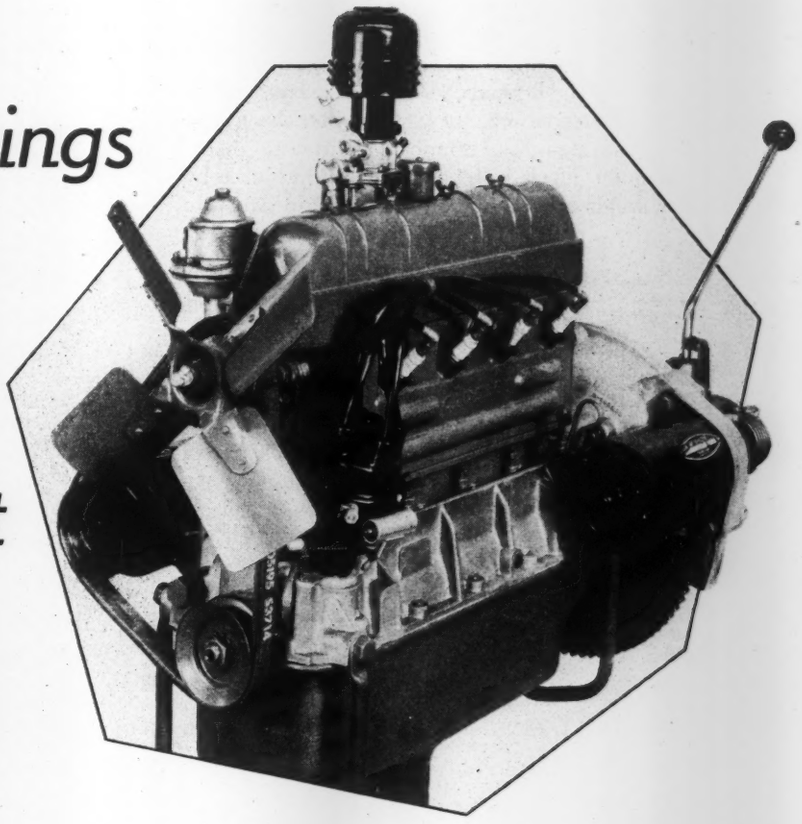
George Gorton Machine Co. (*Figs.* 1, 4, 6, 8, 9, 10 and 11) . . . . . Racine, Wis.
Wickman Corp. (*Figs.* 3, 5 and 6) . . . . . Detroit

Brazed Stampings Reduce Engine Weight



By Paul Klotsch
Chief Engineer
Crosley Motors Inc.

NOT MUCH bigger or heavier than a standard typewriter a new-type automobile engine is powerful enough to give the postwar 1000-pound Crosley car a performance comparable to that of much larger cars. Built on a radically new principle, largely from brazed sheet-metal stampings instead of heavy forgings and castings, the engine weighs only 58 pounds bare but produces up to 26 horsepower. Its cost is a small fraction of that of a standard engine.

The process of making an engine out of brazed stampings is a development of Taylor Engines Inc. The Crosley Corp. became interested in the construction of an engine of this type for the postwar Crosley car and took the exclusive license under all patents and to all developments of Taylor Engines Inc. The engine has proved its value in rigorous service, including the powering of generators for PT boats and amphibious landing tanks. Complete with all accessories for passenger-car service, the engine is illustrated in *Fig.* 1.

Bore and stroke are 2½ and 2¼ inches, respectively, giving a displacement for the four cylinders of 44 cubic inches. The short stroke was selected to keep the piston speed reasonably low when operating at speeds in excess

Fig. 1—Top—Complete with all accessories, the four-cylinder Crosley engine weighs 133 pounds

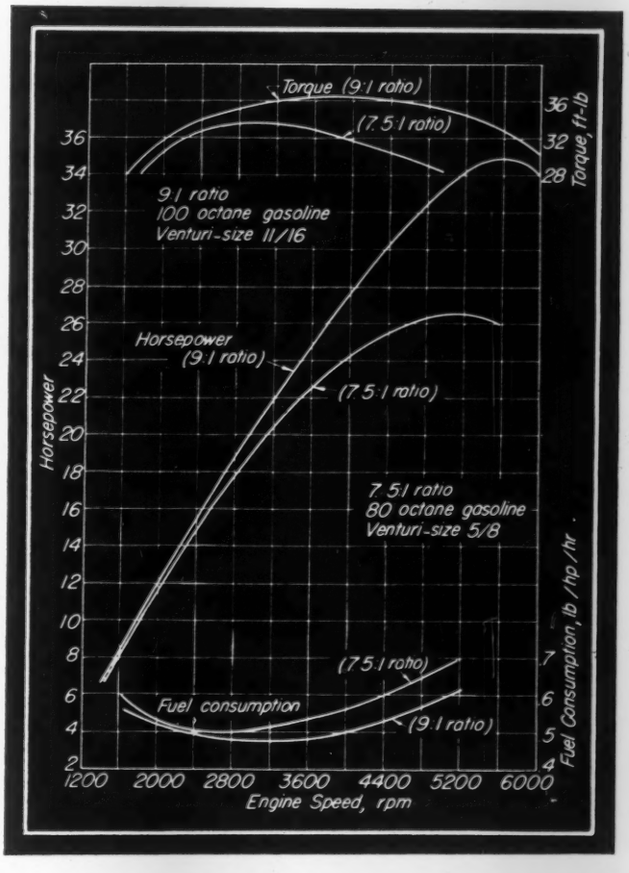


Fig. 2—Right—Performance curves for passenger-car engine (7.5 : 1 ratio) compared with those for high-compression (9 : 1 ratio) engine requiring 100-octane fuel

of 5000 rpm. Performance of the engine, which has a compression ratio of 7.5 to 1, is indicated in *Fig.* 2.

Outstanding feature of the engine is the construction of the cylinder block, *Fig.* 3. Cylinders and cam follower guides are made up of light-walled chrome-molybdenum tubing, while the cylinder heads, intake and exhaust ports, valve cases, and water jackets are plain-carbon sheet steel stampings. These stampings number about 125 pieces for one four-cylinder block. The parts are held in place by press fits, spot welds or crimping and form a firm structure even before brazing. The assembly is then copper brazed in a specially constructed furnace at 2060 F in a neutral atmosphere. Copper is applied to the joints in sheet, wire, or paste form.

At a certain point in the 60-foot long furnace, where the block has been cooled from 2060 to about 1500 F, a cool neutral atmosphere is introduced into the furnace and allowed to circulate around the brazed assembly, which is thereby quickly cooled to about 1100 F. Speed of this temperature drop determines the hardness of the alloy-steel cylinder walls, cam-follower guides, and intake and exhaust valve-seat inserts. The cylinder barrels harden to about 280 brinell and the valve-seat inserts, which are made from a high-carbon tungsten-vanadium alloy, harden to about 450 brinell. Warpage is held to about 1/64-inch in 16 inches by properly designing the stampings as to the height of extrusions, control of press fits, and rate of preheat and cooling in the brazing furnace.

The fabricated cylinder block, as illustrated in *Fig.* 3, weighs 14.8 pounds before machining. Only 1/2-pound of metal is removed during machining, which consists of a light cut from the bottom cylinder plate and the top camshaft bearing, and boring and honing of the cylinder walls and cam-follower guides.

Maximum wall thickness at any point separating the

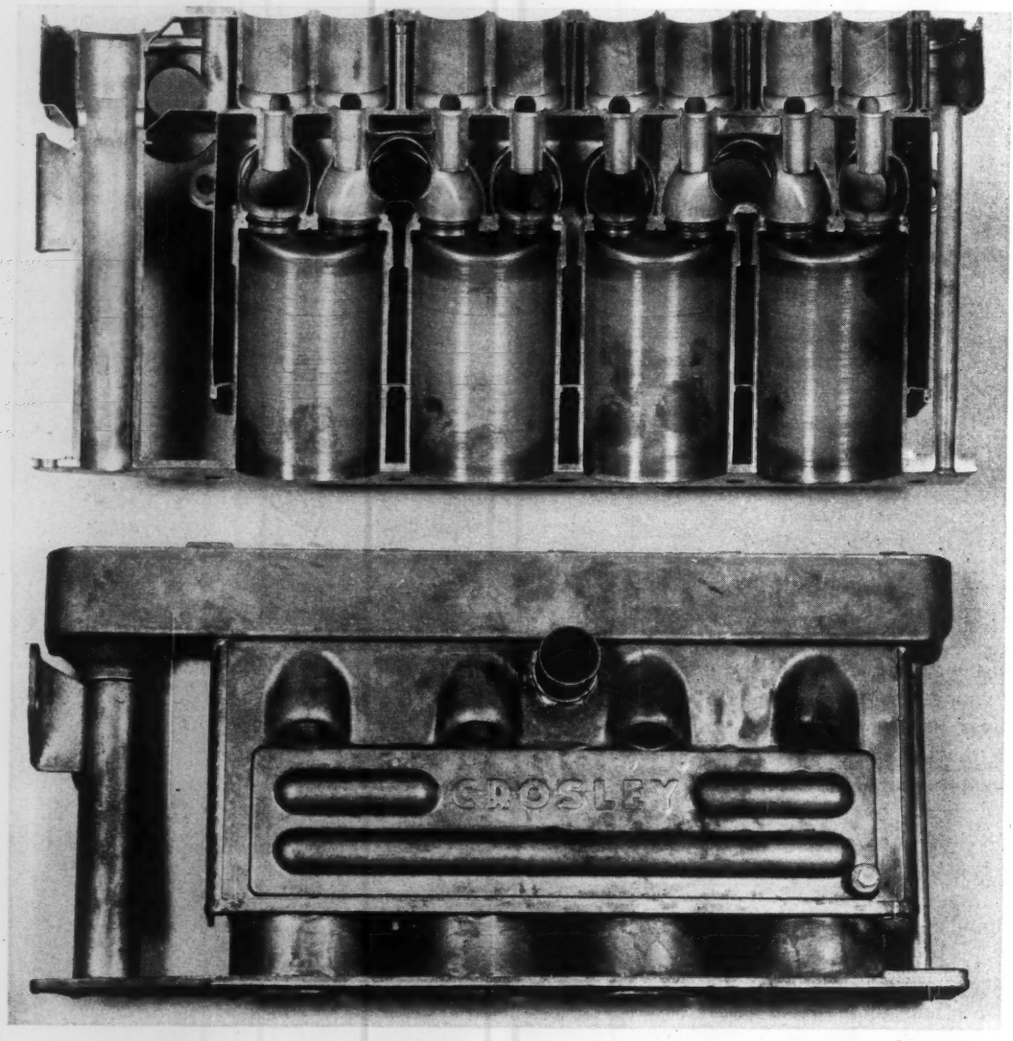
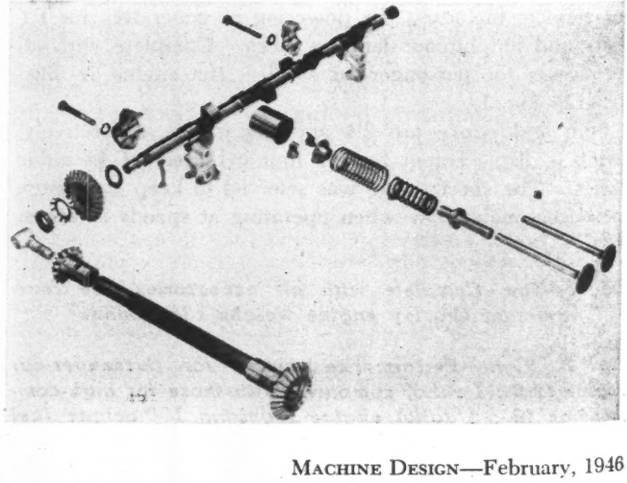


Fig. 3—Left—Cylinder block assembly, showing brazed stamping construction. This part weighs 14.8 pounds prior to machining

Fig. 4—Below—Exploded view of valve-gear assembly, showing bevel-gear drive for overhead camshaft



combustion chamber from the cooling water is 0.125-inch. Because of the uniform thin walls of the fabricated steel construction (*Fig.* 3), including the portion between the valve-seat inserts, and because of the generous contact between these walls and the cooling medium, an even heat distribution is obtained. This prevents the accumulation of heat in certain areas, avoids hot spots, eliminates preignition and permits compression ratios of 9 to 1 to be successfully achieved.

Inside of the water jacket is covered with a clear, hard coat of plastic which, after baking, becomes so durable that it cannot be removed even by a strong caustic or acid solution. Material of the jacket is 20-gage, SAE 1010 sheet steel and the sides are ribbed in such a manner that nothing detrimental occurs to the block if the water in it is frozen solid. This test was made in a cold room at zero Fahrenheit, along with a hand-cranking check which proved that the aluminum crankcase does not shrink enough to cause a noticeable drag on the bearings.

Crankcase Is Permanent-Mold Casting

Crankshaft pulley, fan assembly and fan pulley, and the water pump impeller and pulley also are copper hydrogen-brazed stampings. Crankcase is 3 inches high, weighs 7-3/4 pounds and is a permanent-mold aluminum-alloy casting. Hold-down bolts for the cylinder block extend through the case to the main bearing caps, while the crankshaft thrust is taken at the rear main bearing, which is the only flanged bearing. All connecting rod and shaft bearings are of the precision replaceable type and no machining is required in assembly.

The overhead camshaft, *Fig.* 4, is drilled the full length

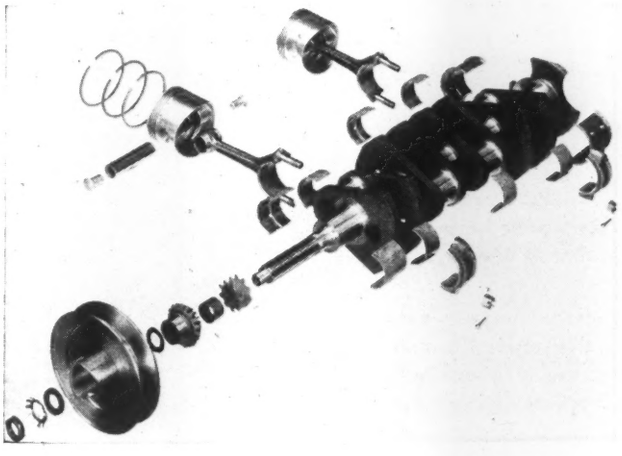


Fig. 5—Cast-iron crankshaft has five main bearings, the journals being induction hardened

for pressure lubrication of the five aluminum camshaft bearings. The cams actuate hardened and ground valve lifters, which are guides in alloy-steel bushings in the cylinder block. Intake and exhaust valve heads are 21-12 chrome-nickel steel and the stems are SAE 3140 steel with flame-hardened tips.

A bevel gear drive was preferred to a chain drive for the overhead camshaft, because the vertical shaft could be used to carry the lubricating oil under pressure to the camshaft bearings, *Fig.* 4. The oil pump and distributor are driven by helical spur gears from the crankshaft. The oil pump, fan, generator, and 12-gpm water pump are driven at 3/4 engine speed.

The five main bearing crankshaft, *Fig.* 5, is a high-strength iron casting with induction-hardened journals. This shaft is designed about one inch shorter than a conventional three-bearing shaft which requires a larger center bearing and an increased shaft length. The crankshaft is in dynamic balance within 1/4 inch-ounce, and the

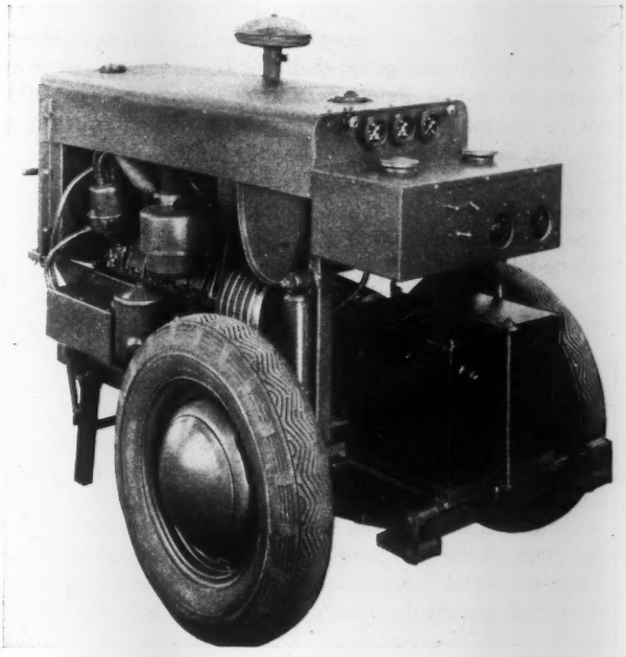


Fig. 6—Portable electric generator unit employing the Crosley-Taylor engine. In this service the engine delivers 20 horsepower at 3800 rpm

vibratory stresses do not exceed 4000 pounds per square inch. One cast shaft underwent a 12,000,000-cycle torsional deflection test, which stressed the shaft to 6000 pounds per square inch without failure.

Pistons are cast from a heat-treated aluminum alloy, the skirts being cam ground and oxidized after final machining. Piston pins are of the floating type with aluminum plugs in each end, *Fig.* 5.

Horsepower-Weight Ratio Tripled

As an indication of the improvement in design over the prewar engine, it is interesting to note that the overall weight has been reduced from 188 pounds to 133 pounds while the maximum horse power has been increased from 12½ to 26½. Using standard high-test gasoline (80 octane) the new engine drove a 1200-pound test car with a 250-pound payload 50 miles per gallon of gasoline at a speed of 30 mph. Even at 55 mph the economy was 35 miles per gallon. Maximum speed of the new car is 65 mph.

In addition to powering the Crosley automobile, the engine is being applied to marine use, farm machinery, refrigeration and air conditioning equipment, motor generators (*Fig.* 6), oil pumps and auxiliary power plants.

Standardization Pays Dividends

By B. C. Boulton*
Engineering Divisional Staff
Douglas Aircraft Co. Inc.

TOO often in a busy engineering department, overloaded with design work, standards engineers are just tolerated or considered overhead, necessary perhaps but not productive insofar as getting on with the main job is concerned. As for having responsible design engineers spend time on standards work—that is just too much even to consider. When pressed, engineering executives will generally agree that standardization has some value but that the benefits are too intangible and too far in the future to warrant more than a low priority in comparison with today's urgent tasks.

If standardization is as important as many who have studied the problem feel, who is responsible for the too general attitude toward it among our operating managements? In considerable part it is felt that the responsibility lies squarely on the doorstep of the standards organization and to a lesser extent of the standards engineer.

The burden of proof that this function may be a highly profitable investment, paying handsome dividends, and recurring ones, is up to those backing it. It must not be overlooked that these dividends are often in the form of enhanced quality of product, frequently not obtainable in any other way. Discussion and generalities have their value but specific facts and figures are needed to convince. A few examples, some from experience of the author's company, others contributed by engineers from other companies, will be presented in the following to illustrate the potentialities of standardization in practice.

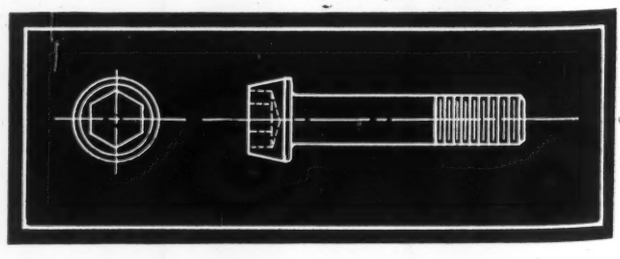
HIGH-STRENGTH INTERNAL WRENCHING BOLT: The story of the high-strength internal wrenching bolt, *Fig.* 1, as used on the Douglas C-54 makes a good beginning. These bolts were originally of Douglas design to conserve weight and space. Each plane utilizes a total of 217 of these bolts ranging in diameter from ¼-inch to one inch. Cost per plane of the Douglas-design bolts was $358.63 whereas that of the standardized NASC (National Aircraft Standards Council) bolts is only $89.89, saving $268.74 per plane. The extraordinary decrease in cost is due largely to more efficient manufacturing methods and the greatly increased production because of wide usage resulting from standarization. In addition, the design changes produced a stronger and lighter bolt, weight saving amounting to 8 pounds per airplane in the case of the C-54.

Cost savings approximate well over $600,000 for the total contracts involved. Without national standardization there would undoubtedly have been some reduction from the prices paid for the Douglas bolts but nothing comparable to the savings attained.

BALL-BEARING PULLEY: The next example is of unusual interest because it is an item used by the million without critical thought and because the standardization has as its objective improved functional quality, cost reduction being a by-product. The part involved is the aircraft ball-bearing pulley. The development of over 300 special pulleys in current use, similar to the AN210 series, came about as the result of the latter's inadequacies.

In working up the design of the proposed NASC series, *Fig.* 2, the subcommittee first made an analysis of functional and design requirements. The fundamental change is in the pulley capacity ratings which are based on the "limit" load in the airplane cable system. The resultant pulley load, with a safety factor of 2, and the allowable bearing stress of the sheave material determine the sheave design. With the AN (Army-Navy) series, only the bearing was protected by the rated capacity and the sheave could be so overloaded as to

Fig. 1—Below—Standardization of this internal wrenching bolt saved $268 and eight pounds in weight per airplane



*The author is now engaged with Harry Ferguson Inc., Dearborn, Mich.

This article is based on a paper presented at the Aviation War Conference of the American Society of Mechanical Engineers in Los Angeles, Calif.

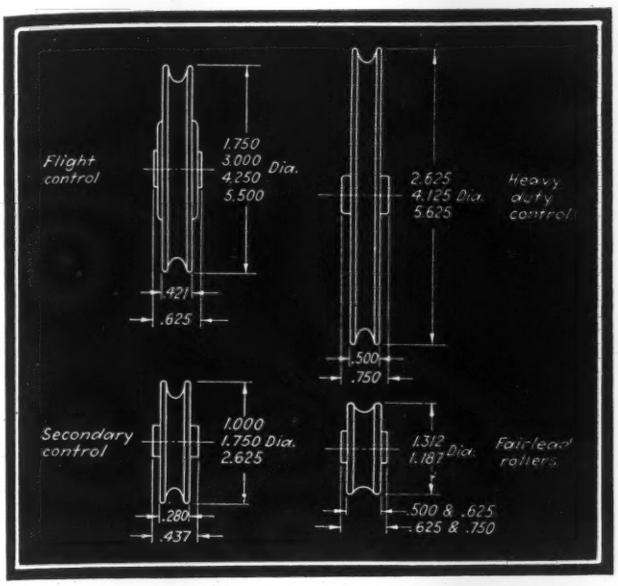


Fig. 2 — Above — Proposed pulley standard improves design and reduces number of special designs

cause early failure. To aid the designer in intelligent selection of a pulley for a specific application, with due regard for pulley and cable life, the NASC standard drawings contain two S-N curves, one for the sheave and one for the cable, *Fig.* 3.

The bearings will be specially designed to meet pulley requirements. The hubs will project sufficiently to provide adequate clearance and will be wide enough to permit a double-row ball or needle bearing much lighter, giving more stability than the present single row. An important feature of the secondary-control pulleys for engine controls is the provision, in two sizes, of a 0.625-inch bore to permit gang mounting on a tube. The pulley, designed from definite performance specifications, makes possible a weight saving of about 40 per cent on flying-control pulleys.

Because it shows so clearly why a properly developed modern standard excels from both a quality performance and production viewpoint, a summary is given of the development of the NASC pulley. The initial proposal was prepared by R. R. Richolt, hydraulic and mechanical staff engineer for Lockheed, and a representative of a bearing manufacturer. This was presented to the NASC controls subcommittee and their suggestions incorporated. A design-policy questionnaire was sent to all aircraft companies for comment, followed by a conference of twelve leading pulley and bearing manufacturers, working with two aircraft engineers. They studied the proposal in detail and made recommendations. Then a special panel representing the three groups concerned was chosen to draft the final design envelope and performance requirements. These have now been submitted to all aircraft companies for final comment and approval.

Once the pulley and bearing manufacturers understood that the proposal was for postwar manufacture and would not upset war production, they were heartily in favor of it as they have experienced difficulties under present conditions and do not relish manufacturing 300 special pulleys. Under the proposal, 20 pulleys cover all

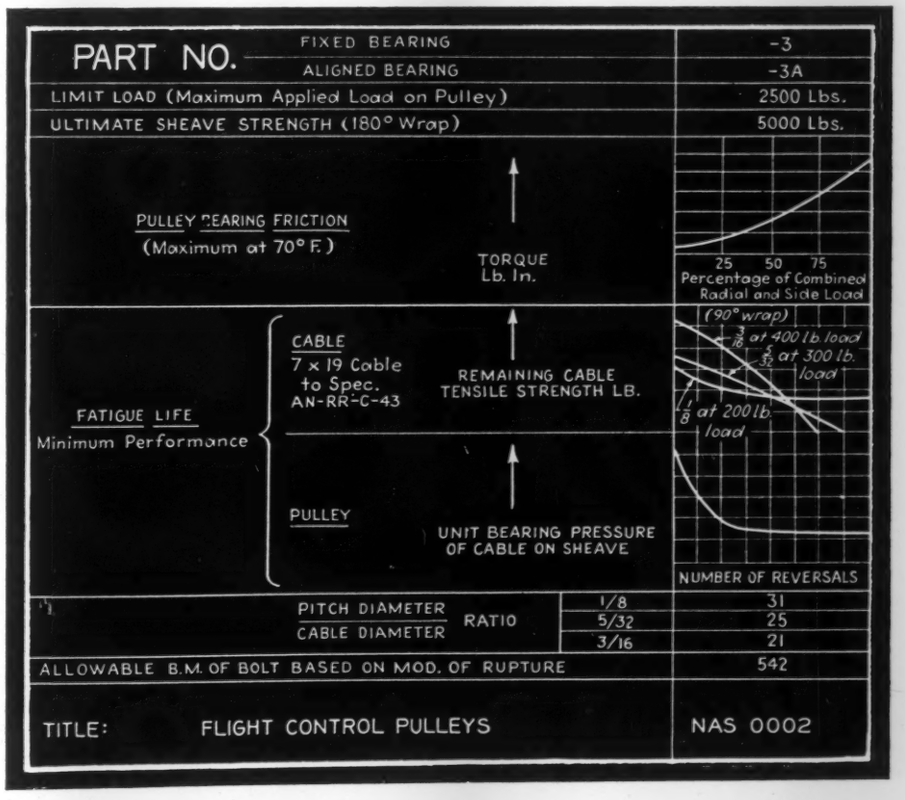


Fig. 3—Right—Engineering data on NASC pulley drawings contain S-N curves

requirements, including those for heavy-duty and fair-lead pulleys, and will not have to be supplemented except in minor degree. Their cost will be about the same as for AN210 pulleys. A large cost saving, however, will occur as a result of elimination of the "specials."

HYDRAULIC FITTINGS: In complete contrast to the preceding example is the case of standardization of the AC811 series of hydraulic fittings, *Fig.* 4. For new design and some current models, this series was superseded by a new series of AN fittings, but for several airplanes in large production no change was made. The AC811 series was originally proprietary and made by one manufacturer. However, procurement demands were so great that several sources had to be developed. One difficulty was that the available drawings, as released by the Army, were not completely dimensioned; critical dimensions were specified by a tool number. Much confusion arose in interpreting these drawings, and supposedly identical parts produced by different vendors differed.

Finally the Lockheed Company sponsored an NASC project for the preparation of a set of standard drawings. Slight changes in design and in tolerances made it possible to machine the fittings with standard tools on automatic equipment, saving considerable tooling and manufacturing time. The NASC proposal was presented to the Services and resulted in issuance of WPD Directive 6-W-2. Cost reductions resulted in savings up to 56 per cent on these fittings.

In 1944 the Lockheed company, as a result of this work, saved $406,000 over previous prices and greatly facilitated its procurement.

FUEL-CELL FITTINGS: The next illustration, contributed by North American Aircraft corporation, is typical of

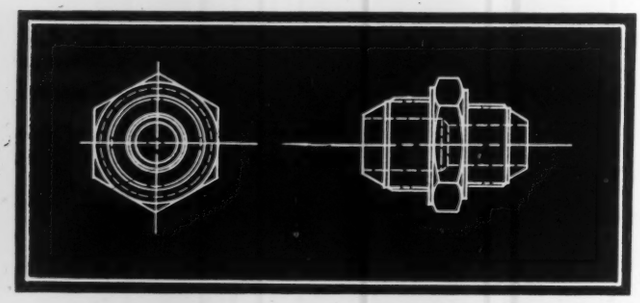


Fig. 4—Standardization of connector fittings permitted increased sources of supply as well as reduced cost

extremely useful standards work and is of interest because it demonstrates the considerable savings in engineering design time which frequently result from standardization. It is the design of a set of standard self-sealing fuel-cell fittings, undertaken by the Air Technical Service Command in co-operation with the major rubber companies. These cover various sizes of single and two-plane fittings from which an engineer can select in designing a fuel cell.

Prior to the advent of these standards, a choice might be made either from a multitude of existing fittings, if drawings were on hand, or a new fitting drawn up. In general, molds for existing fittings were available to only one or two vendors. If an order were placed elsewhere, the cost of new tooling and a procurement delay of 3 months or more were involved. Now each vendor has molds for all standard fittings. Thus this standardization project has the following advantages:

1. Provides a set of standard fittings from which an engineer can choose, eliminating investigation into available nonstandard types, except in unusual cases
2. Eliminates the necessity for detailing fittings with each cell; in a typical case, 48 drawings and 500 engineering hours were required for such drawings for one tank
3. Reduces procurement time and cost.

Specified Finish Aids Shop

SURFACE FINISH: The NASC project for the development of standards to designate surface finish would appear to be of the somewhat theoretical type with the practical benefit rather long range and a bit hazy. Judging from the recent experience of North American Aircraft quite the contrary is true. The benefits have been most tangible in the form of 15 per cent reduction in scrap, and 40 per cent reduction in rework of hydraulic parts. In addition to these gains, the foreman of the machine shop stated that the clear designation on the drawing of the quality finish desired on specific surfaces saved much time formerly wasted in misapplication of effort. It had eliminated time-consuming arguments between shop and inspection and the necessity for frequent contacts between engineering and the shop, particularly important in the case of outside production. Parts from the machine shop are of more uniform quality than before the adoption of the NASC designation of finish in microinches and the use of standard comparators to measure it. Leakage problems have almost disappeared.

No attempt is made to place a monetary value on such results. The economic gain to industry from a standard which provides a means for designating quantitatively and measuring qualitatively the surface finish is self-evident. Although the aircraft industry has adopted as its unit of measurement the "rms or root-mean-square" value of surface irregularities, the acceptance of this unit is by no means universal. There are five other proposed systems of measurement, each with strong proponents. The need is urgent for a meeting of minds and a redrafting in definite form, for national and international use, of the American Standard Association's standard on surface finish.

Although only a few examples have been given of the almost countless number available, they demonstrate the various ways intelligent standardization brings about major improvements in quality and lower overall manufacturing costs, as well as reduced procurement time, and greater availability due to increased sources. These benefits are neither intangible nor long-range; they are here and now; they do not stop but are permanent gains paying dividends month after month. In postwar industry it will be the individual company's money on fixed-price contracts which will be saved.

The benefits from a standard are more than proportional to the quality and soundness of that standard. Top engineering executives should make clear, down the line of organizational authority through the operating level that, when the need arises, a design engineer should be assigned to standards work as a part of his legitimate activity so that he is not made to feel that he is neglecting his job and his company's interest.

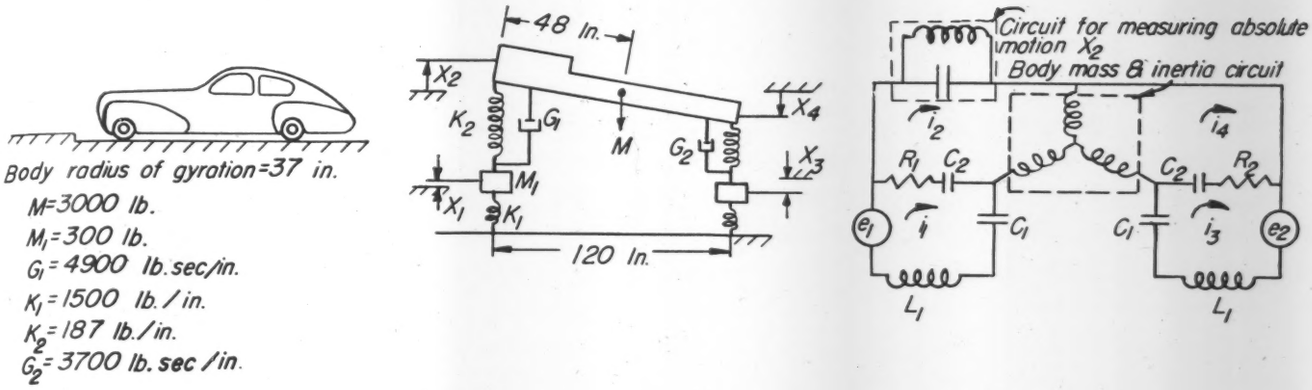


Fig. 10—Passenger car about to encounter road bump, left. Simplified dynamic system is shown in center and analogous electrical circuit at right. Symbols K_1 and K_2 represent tire and spring stiffnesses, G_1 and G_2 are shock absorber constants

Solving Complex Problems by Electrical Analogy

By G. D. McCann and H. E. Criner
Westinghouse Electric Corp.

Part 2

IN PART I of this article, which appeared in the December, 1945, issue, the mechanical transients analyzer was discussed, and it was shown how this machine could be used to solve mechanical problems by means of electrical analogies. In this concluding portion it is shown how other problems in mechanical and electromechanical systems may be solved by this method.

RIDABILITY OF A VEHICLE: The example of *Fig.* 10 illustrates the application of the electrical-mechanical analogy to the combination of translational and rotational motion (in this case plane motion). When relatively small angular motion is assumed, analogous circuits can be developed even when the motion is not confined to a plane. In these cases the circuits for all masses must combine both mass and rotational inertia constants. They become either multiwinding transformers or multiterminal networks.

For the vehicle shown in *Fig.* 10 the motion of the wheels and body as the car passes over a stepped surface in the roadway at a given velocity was to be determined. The vehicle was represented by the simplified dynamic system shown at the center of *Fig.* 10, the analogous electrical circuits being shown at the right of the same figure. Constants used in this problem were assumed but are comparable to those found on commercial vehicles.

When the mass-inductance analogy is used the effect of the stepped surface in the roadway is introduced into the electrical circuit by the voltages e_1 and e_2. Voltage e_1, which is proportional to the sudden displacement of the

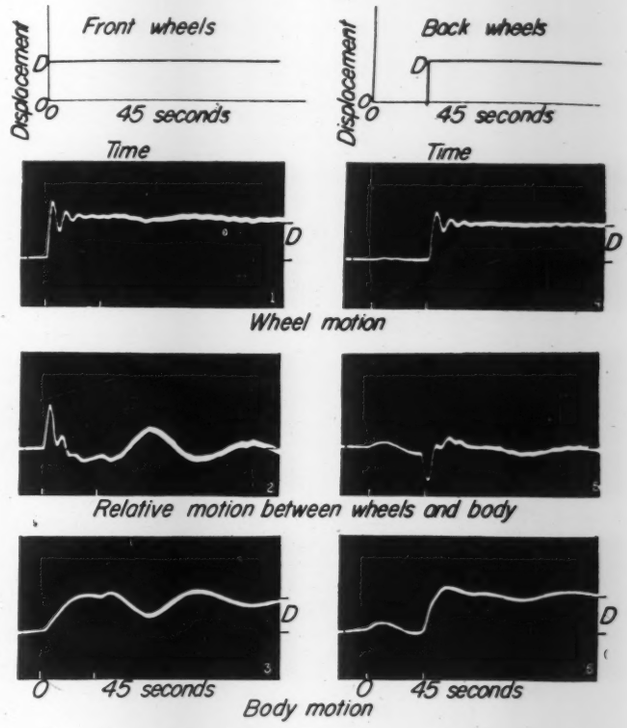
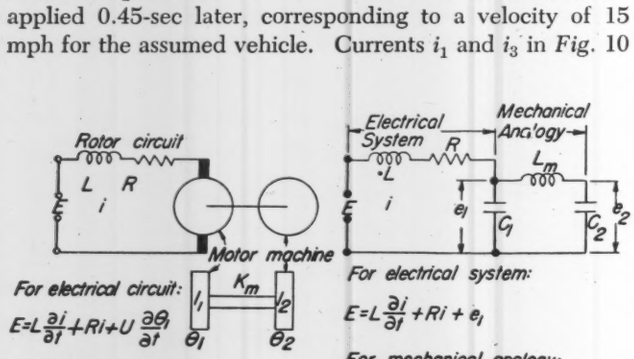


Fig. 11—Above—Oscillograph records show automobile wheel and body motions after encountering road bump

bottom of the front tires, is a constant voltage suddenly applied at time zero. Voltage e_2, which represents the sudden displacement of the bottom of the back tires, was applied 0.45-sec later, corresponding to a velocity of 15 mph for the assumed vehicle. Currents i_1 and i_3 in *Fig.* 10 are the analogous velocities of the wheels, while currents i_2 and i_4 are the analogous velocities of the two ends of the body. Displacement of the wheels and the relative displacement between wheels and body are proportional to the voltages across C_1 and C_2, respectively, and are shown in the oscillograms in *Fig.* 11.



For electrical circuit:

$$E=L\frac{\partial i}{\partial t}+Ri+U\frac{\partial \theta_1}{\partial t}$$

For mechanical system:

$$Gi=I_1\frac{\partial^2\theta_1}{\partial t^2}+K_m(\theta_1-\theta_2)$$

$$0=I_2\frac{\partial^2\theta_2}{\partial t^2}-K_m(\theta_1-\theta_2)$$

For electrical system:

$$E=L\frac{\partial i}{\partial t}+Ri+e_1$$

For mechanical analogy:

$$i=C_1\frac{\partial e_1}{\partial t}+\frac{1}{L_m}\int(e_1-e_2)\,dt$$

$$0=C_2\frac{\partial e_2}{\partial t}-\frac{1}{L_m}\int(e_1-e_2)\,dt$$

Where $C_1\equiv\frac{I}{UG}$; $C_2\equiv\frac{I_2}{UG}$

$$\frac{1}{L_m}=\frac{K_m}{UG}$$

$$e_1=U\frac{d\theta_1}{dt};\ e_2\equiv U\frac{d\theta_2}{dt}$$

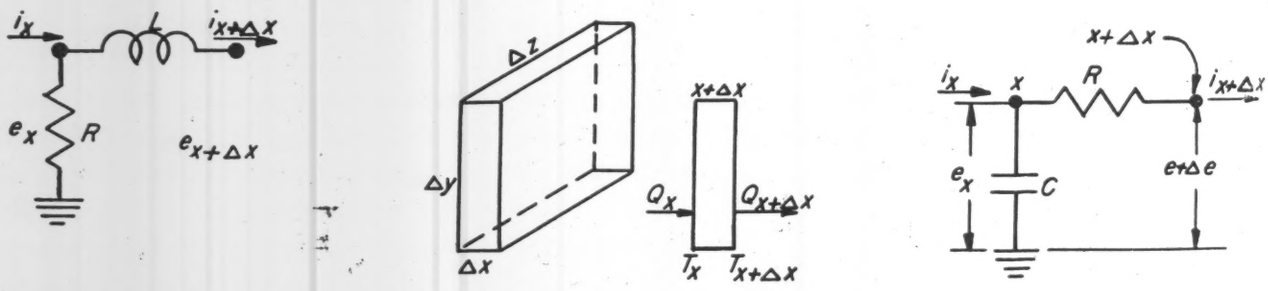
Fig. 12—Above—Separately excited d-c motor-driven machine and its equivalent circuit, using current-force capacitance-inertia analogy for mechanical system

Absolute motion of the body cannot be determined directly from the mass-inductance circuit. However, reasoning from the mechanical system, it is apparent that this motion could be measured by suspending a mass from a very weak spring at either end of the vehicle. If this auxiliary system is adjusted so that its period is long compared to the period of the body motion, the relative displacement between the body and the suspended mass will be a measure of the absolute body motion. The electrical analog of this system is a large capacitance shunted by an inductance placed in the circuit (see *Fig.* 10) so that i_2 or i_4 must flow through the combination. Voltages developed across the capacitor are proportional to the body motion. Oscillograms of these motions are shown at the bottom of *Fig.* 11.

While no effort has been made to present a complete analysis of the ridability problem, it is evident that the mechanical-transients analyzer, as described in this article, provides a means for studying a wide variety of designs and the effect of various road surfaces on the motion of the vehicle.

ELECTRO-MECHANICAL SYSTEMS: Devices that comprise the interaction of several types of physical systems are usually considerably more complex than is the case when

Fig. 13—Below—Derivation of the analogs for one-dimensional heat flow through a solid conducting medium



Analogous temperature-current electrical circuit

$$L=(\Delta x\ \Delta y\ \Delta z)c\rho;$$

$$R=\frac{\Delta x}{(\Delta y\ \Delta z)k}$$

$$e_{x+\Delta x}-e_x=L\frac{\partial i}{\partial t}$$

$$e_x=-\frac{1}{R}(i_{x+\Delta x}-i_x)$$

One-dimensional element of thermal conducting medium

Law: Rate of heat storage in element is product of thermal capacity and rate of increase of temperature

$$Q_{x+\Delta x}-Q_x=-(\Delta x\ \Delta y\ \Delta z)c\rho\frac{\partial T}{\partial t}$$

Law: Flow of heat is in direction of greatest temperature drop and proportional to rate of change of temperature

$$Q_x=-(\Delta y\ \Delta z)\,k\frac{T_{x+\Delta x}-T_x}{\Delta x}$$

Symbols: Q = rate of heat flow per unit time across given surface; T = temperature; c = specific heat; k = thermal conductivity; ρ = density

Analogous temperature-voltage electrical circuit

$$C=(\Delta x\ \Delta y\ \Delta z)c\rho;$$

$$R=\frac{\Delta x}{(\Delta y\ \Delta z)k}$$

$$i_{x+\Delta x}-i_x=-C\frac{\partial e}{\partial t}$$

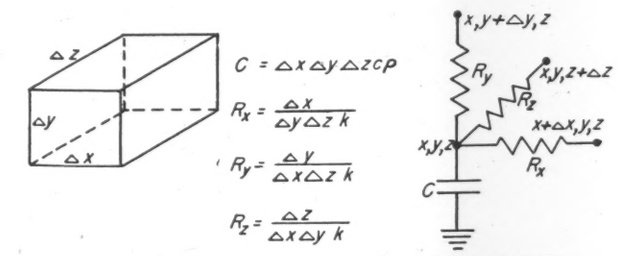
$$i_x=-\frac{1}{R}(e_{x+\Delta x}-e_x)$$

one system is involved. The method of electrical analogy can thus become a particularly powerful tool in this field. The more common interacting systems are electrical and mechanical systems, typical of which are various electric motor drives such as motor-generator sets, electrodynamic speakers, voltage and speed-regulating systems, and many other servomechanisms. The simple example of *Fig.* 12 illustrates the general method of setting up an all-electrical analogy to represent such systems. In this case it was found more convenient to use the mass-capacitance circuit for the mechanical system. Then the voltage e_1 of *Fig.* 12 (which is proportional to the velocity of the motor rotor) represents the internal voltage of the motor.

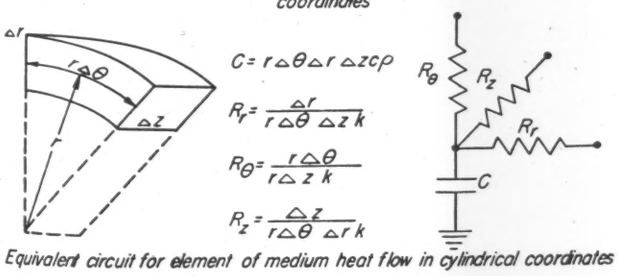
Approximating Distributed Constants

HEAT FLOW: One of the most complex types of problems from the standpoint of mathematical analysis is one in which the physical phenomena take place in a distributed irregular region or medium. Examples of this are high-frequency electromagnetic wave propagation through space or wave guides, etc., flow of current in a conducting medium of irregular shape, and the flow of heat in a thermal conducting medium. Most practical shapes are such that adequate analysis is impossible by conventional methods. However, for several types of physical systems of this nature it is possible to derive an analogous lumped-constant electrical circuit that accurately represents a differential volume of the medium.

An example of this is illustrated here by the analog for heat flow through inert conducting media. The fundamental laws for heat flow and the derivation of their analog are given in *Fig.* 13 for simple one-dimensional flow. As shown, two analogous circuits can be used, one in which temperature is represented by voltage with rate of heat flow represented by electric current, and the other in which temperature is represented by current with heat flow represented by voltage. The former analogy is usually more practical, since it is easier and cheaper to build, with sufficiently low loss, than inductors. *Fig.* 14 shows the form of the analogous circuits in three dimensions.



Equivalent circuit for element of medium of heat flow in Cartesian coordinates



Equivalent circuit for element of medium heat flow in cylindrical coordinates

Fig. 14—Electrical analogies for three-dimensional heat flow using Cartesian and cylindrical coordinates

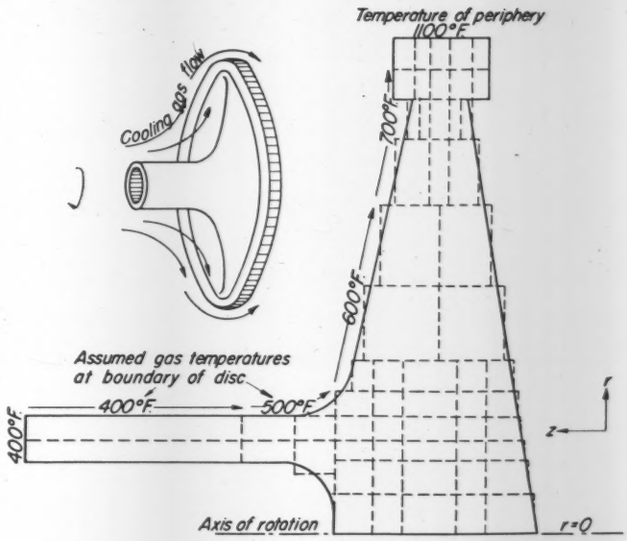
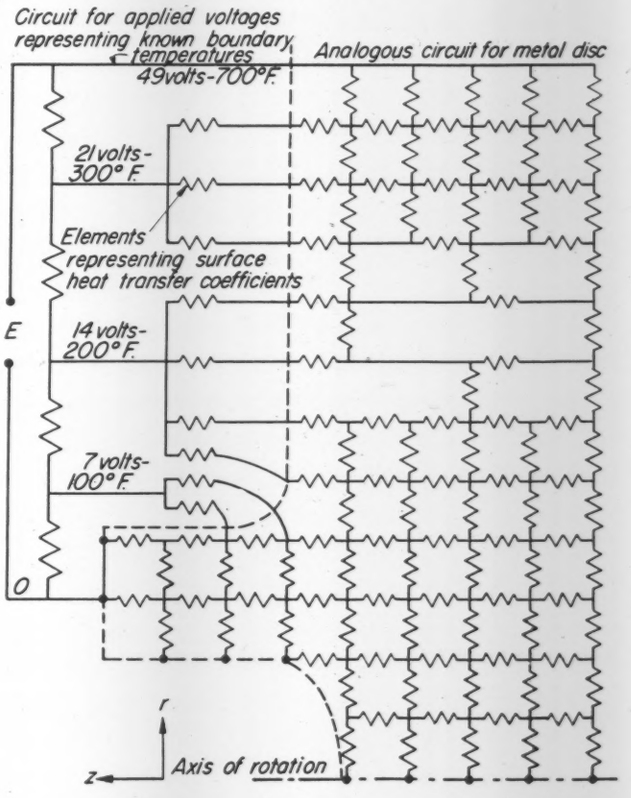


Fig. 15—Typical heat flow conditions in a gas turbine disk, showing the known boundary conditions and the method of setting up heat transfer elements

For a given system the body is divided into volume elements whose size is governed by the configuration of the body, boundary conditions, and the required accuracy of the solution. For each element the analogous circuit consists of a capacitance representing the thermal capacity of the element and three resistances each representing the temperature gradient per unit of heat flow per unit time through the element in the direction of the respective coordinate. Connection of the resistances into a grid, in ac-

Fig. 16—Below—Electrical analog of turbine disk of Fig. 15. Capacitors are omitted for steady state solution

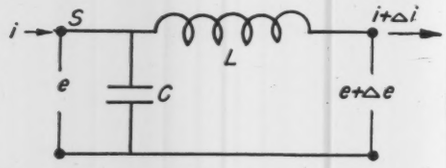


cordance with the respective positions of each element, and connection of the bottom terminal of all capacitors to a common ground form the analogous circuit representing the entire body.

Choice of coordinate system depends, of course, upon the shape of the body and the boundary conditions of the problem. Where symmetry with respect to one axis exists, a two-dimensional circuit results. The differential dimension of the elements in the direction of the axis of symmetry is the entire dimension of the body at the respective values of the other two coordinates. Coefficients of surface heat transfer also can be represented by resistances. The choice of magnitude of the electrical circuit elements and the relations between the measured electrical quantities and the two solutions can be determined exactly as shown in TABLE I, which appeared in Part 1 of this article.

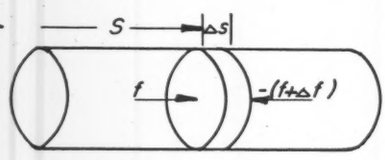
For transient problems the transient boundary conditions can be generated as excitation functions by the circuit methods employed in the mechanical transients analyzer.

(*Concluded on Page 157*)



Analogous mass-capacitance, force-current electric circuit

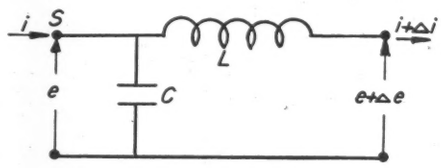
$i \equiv f,\ e \equiv V,\ C \equiv \rho A \Delta s,\ L \equiv \frac{k \Delta s}{A^2}$



Hydraulic system

Acceleration force in volume of liquid in element Δs

$= \rho A \Delta s \frac{dV}{dt}$



Analogous mass-inductance, force-voltage electric circuit

$e \equiv f,\ i \equiv V,\ L \equiv \rho A \Delta s,\ C \equiv \frac{k \Delta s}{A^2}$

By Kirchhoff's First Law:

$$i-(i+\Delta i)-C\frac{de}{dt}$$

$$\Delta i + C\frac{de}{dt} = 0$$

By Newton's Second Law:

$$f-(f+\Delta f)-\rho A \Delta s \frac{dV}{dt} = 0$$

$$\Delta f + \rho A \Delta s \frac{dV}{dt} = 0$$

Total volume of fluid forced into element s

$$= k \Delta s \frac{\Delta f}{A}$$

By Kirchhoff's Second Law:

$$e-(e+\Delta e)-L\frac{di}{dt} = 0$$

$$\Delta e + L\frac{di}{dt} = 0$$

By Kirchhoff's Second Law:

$$e-(e+\Delta e)-L\frac{di}{dt} = 0$$

$$\Delta e + L\frac{di}{dt} = 0$$

By Continuity Equation:

$$AVdt-A(V+\Delta V)dt-k\Delta s\frac{\Delta f}{A} = 0$$

$$\Delta V + \frac{k \Delta s}{A^2}\frac{df}{dt} = 0$$

By Kirchhoff's First Law:

$$i-(i+\Delta i)-C\frac{de}{dt} = 0$$

$$\Delta i + C\frac{de}{dt} = 0$$

Symbols:

s = differential length of conduit;

f = total force on a given cross-section

A = cross-sectional area of conduit;

t = time

ρ = density of fluid;

k = volume forced into unit length per unit increase in pressure

***Fig. 17**—Above—Analagous circuits for differential elements of a conduit or pipe carrying fluid. Series of such elements is electrical equivalent of finite length of pipe*

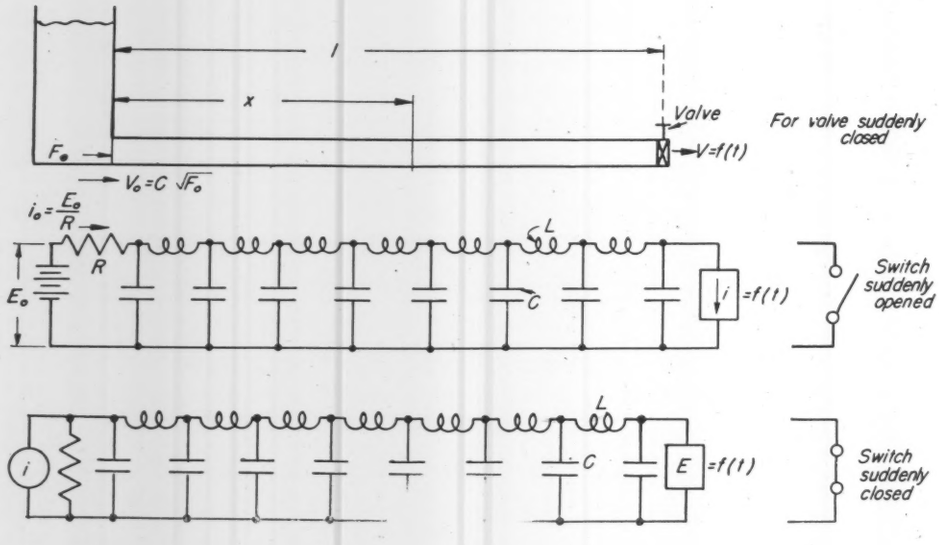


***Fig. 18**—Electrical analogy for determining flow and pressure in a penstock when valve is suddenly closed*

Drafting-Room Practice

PROS AND CONS of ten basic principles covering the dimensioning and tolerancing of drawings with respect to interchangeable components were discussed at the Ottawa conference held last fall on the unification of engineering standards. Delegations from the United States, Great Britain and Canada took part. It is felt that a resume of the proceedings, based on a section of the official report of the meeting issued by the sponsoring body—the Combined Resources and Production Board—will be of basic interest and will stimulate discussion and comments leading toward the establishment and use of mutually satisfactory standards.

FOLLOWING the international conference on engineering standards held in London in 1944 and attended by American, British and Canadian delegates, there was a continuation of activity in the United Kingdom toward establishing principles for the dimensioning and tolerancing of drawings. An Inter-Service committee was set up to pursue the earlier work carried out by an Admiralty committee and to establish a system suitable for use in all Service drawing offices.

Early in 1945, in response to invitations received from the American Society of Mechanical Engineers and the Society of Automotive Engineers, C. A. Gladman of the National Physical Laboratory came to the United States and Canada for the purpose of presenting his paper "Drawing Office Practice in Relation to Interchangeable Components" to groups of engineers in some twenty cities. Con-

siderable interest was created in America as a result and at the request of the United States War and Navy Departments, the American Standards Association formed a war committee to study the whole problem. At the same time, an "Ordnance Manual on Dimensioning and Tolerancing" was prepared by the inspection gage suboffice of the United States Chief of Ordnance.

Project Outlined at Conference

The British, in outlining the scope of the subject from their viewpoint at the recent Ottawa conference, emphasized that the keynote was contained in the last five words of the title adopted by Mr. Gladman for his paper, namely: "in relation to interchangeable components."

It was reported that there already is a British standard on drawing office practice, dealing with sizes of drawing paper, thickness of projection lines, types of printing, etc. The particular phase of drawing practice, however, which has been the subject of intensive study in Great Britain during the last three or four years, deals more specifically with the thought and technique which must be applied to

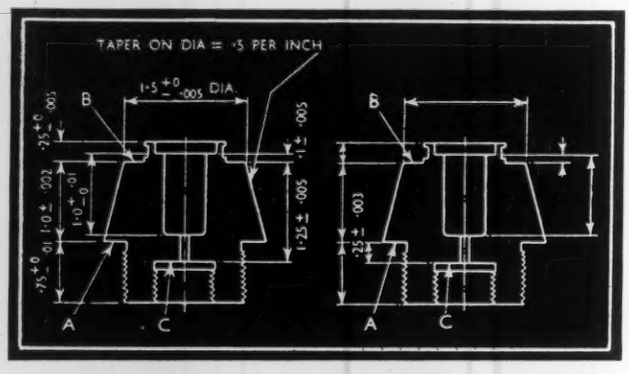


Fig. 1—Change in dimensioning shown in drawing at right typifies Principle 4 which calls for changes in datum or basic surfaces to facilitate production and inspection

the dimensioning and tolerancing of drawings to insure the inclusion of all data required for production and inspection.

The Canadian delegation reported that there had been no organized study of the subject in their country, but stated that Canadian engineers were keenly alive to its importance, particularly in view of the fact that Canada was required to produce, during the war, much equipment from drawings which did not originate in their country. In general, Canadian practice, particularly in peacetime, has been to follow the practice established in the United States.

The American delegation stated that the desirability and importance of developing a unified drawing practice was fully recognized. It was reported that, as a result of the presentation of the paper by Mr. Gladman throughout the United States, a series of discussions was initiated by various engineering organizations. In the summer of 1945, the American Standards Association appointed a subcommittee of the Sectional Committee on Drawing and Drafting Room Practice, ASA Z14, to study the Gladman paper and to report its comments on the various principles discussed. This subcommittee met in July and as a result prepared a paper "A Critical Review of Drafting Room Practice in Relation to Interchangeable Components" for presentation at the conference.

Immediately prior to the conference a series of British papers on drawing practice had been received by the American subcommittee but it was not possible in the time available to give them careful consideration. Arrangements were made to review these documents at the earliest opportunity.

It was agreed by the delegates from the three countries that the first session on drawing practice should be confined to the "Critical Review" of Mr. Gladman's paper submitted by the American delegation. The discussion therefore proceeded on that basis, as summarized in the following.

PRINCIPLE (1) of the Gladman paper reads:

> The requirements relating to interchangeability should be determined from the following considerations:
>
> (a) Service conditions, namely, maintenance and spares.
>
> (b) Economy of manufacture and inspection.

The British delegates agreed to the United States proposal to insert the word "assembly" in (b) after "manufacture."

Arising out of this principle, considerable discussion took place on the difference between *universal* interchangeable manufacture and *local* interchangeable manufacture, defined in Gladman's paper as follows:

> Universal Interchangeable Manufacture—Parts made in different factories or organizations are required to be mutually interchangeable.
>
> Local Interchangeable Manufacture—Only parts made in the same factory or organization need be interchangeable.

Local interchangeable manufacture, the American delegates claimed, should not be considered when setting up a system of dimensioning and tolerancing drawings involving any system of symbols. The British delegates disagreed with this view and felt that their object in distinguishing between the two types of interchangeable manufacture had not been fully understood in America. They explained that universal interchangeable manufacture was clearly essential in the manufacture of many armament stores such as weapons and ammunition which are of necessity produced in many different factories to definite limits of size. It was pointed out that cases arise, however, even in armament work, where it is only necessary for a unit, as a whole, to pass a functioning test without the individual components of such units being interchangeable between units made by different manufacturers. Where such units have to assemble with others to form a complete assembly it is necessary, then, to have universal interchangeability for those dimensions relating only to the points of attachment.

Their "special" system of dimensioning and tolerancing, it was further pointed out by the British delegates, incorporated a means for distinguishing on certain armament drawings those dimensions and tolerances which *must* be rigidly adhered to where *universal* interchangeability was involved. For industrial drawings, however, the British delegation agreed that no such distinction was necessary

nor was it included in their "standard" system of dimensioning and tolerancing for use on such industrial drawings.

Continuing their review of the American comments on the principles stated in Gladman's paper, the British delegates mentioned that a further principle had now been included stressing the importance of the use of standard articles, forms and sizes. This further principle was embodied in Sheet D. C. 85, one of the British papers prepared for presentation at the conference.

PRINCIPLE (2). The United States delegates were essentially in agreement with this principle which reads:

> The features of a component should be carefully studied and basic sizes should be directly associated with those dimensions which affect functioning and, or alternatively, assembly. (The basic size of a dimension is the size in relation to which all limits of variation are assigned, i.e., it is the size which would be used if it were possible to work without tolerances. In the following discussion this size is, for brevity, referred to as the basic dimension.)

PRINCIPLE (3) of Gladman's paper is as follows:

> Where variations from the desired functioning and, or alternatively, assembly requirements can be permitted only in one direction, appropriate unilateral tolerances should be assigned to the relevant basic dimensions of components. Where variations can be permitted in both directions, bilateral tolerances should be used. (Unilateral tolerances are given on one side only with respect to the basic dimensions; bilateral tolerances are given on both sides.)

The only alteration which the American delegates proposed in this principle was the substitution of the word "may" for "should." The British did not agree with this and the point was left open pending clarification of the exact meaning of the terms in the different countries.

PRINCIPLE (4). Discussions took place on the minor criticism of this principle which reads:

> Datum surfaces selected from functioning considerations should be replaced, where necessary, by others specially selected for the purpose of economical manufacture and, or alternatively, inspection. (See *Fig.* 1, the drawing shown being reproduced from the original Gladman paper.)

PRINCIPLE (5) states:

> The distance between any two points or surfaces should be limited in not more than one way.

This was agreed to, but the British delegates drew attention to the more explicit statement of this principle given in their Sheet D. C. 85, referred to previously. They also stated that when an untoleranced overall dimension is given they recommend that it should be marked "calc" (an abbrevation of calculated) rather than "ref" (reference) as suggested by the American delegates.

PRINCIPLE (6) of Gladman's paper reads:

> Fits between mating parts should be obtained in general on the hole basis. The shaft basis should only be used in special cases where the hole basis is not suitable.

In commenting on this the American delegates considered no particular preference should be stated for the "hole" basis and that the use of the "shaft" basis should be optional. The British delegates proposed and it was agreed that this point could best be left for discussion at the tenth session of the conference, on "Limits and Fits in Engineering."

PRINCIPLE (7) is as follows:

> Clearances or interferences should be established with due regard for the effect of "inspection" gage tolerances.

The British delegates noted with interest that the American comments indicated approximate agreement between the practice of the two countries as regards the magnitudes of the tolerances on gages, but considered that any detailed discussion on gages should be reserved for the thirteenth session of the conference on "Metrology in Mechanical Engineering."

The American delegates agreed to the usefulness of a chart in the Gladman paper which gives the accuracies ordinarily obtainable by different methods of machining and suggested that similar information could be usefully added for punched holes, pressed and coined parts, powder-metal parts, die and wax castings and plastic molded parts. The British delegates stated that they would be interested to have such information if it were available in the United States.

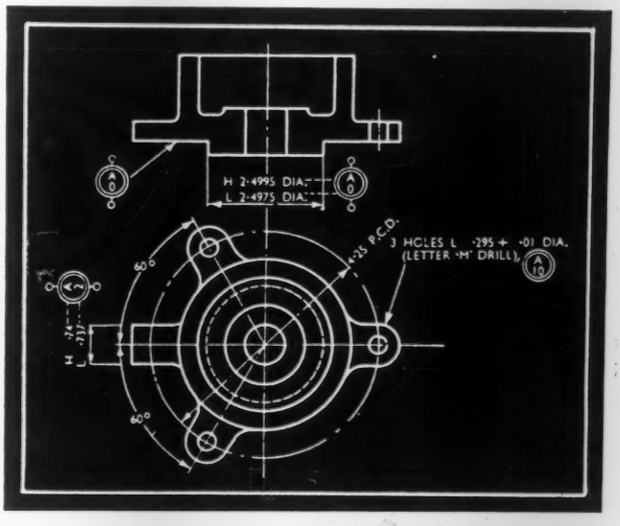


Fig. 2—Double circles, enclosing group letters and tolerances, are indicative of symbols suggested for position, concentricity, etc. No agreement was reached on these

Propose Correlation of Production Data

The British delegates drew attention to the information on production accuracies which is obtained in employing "Quality Control." They suggested that this information might usefully be collected and analyzed by a central body in each country with the view toward collaborating on the publication of reliable data on the accuracy ordinarily obtained in machining and forming metals, plastics, etc.

PRINCIPLE (8). A brief discussion took place on this

principle which states, in relation to tolerances:

> Tolerances assigned to components should be scrutinized carefully to insure that no special difficulties in production or inspection have been imposed without real functional necessity. (Tolerances on jigs, fixtures, and tools are approximately 20 per cent of the corresponding component tolerances; tolerances on gages are approximately 10 per cent of the corresponding component tolerances.)

The American delegates considered that the tolerances on jigs, fixtures and tools should be given as 20 to 50 per cent of the corresponding component tolerances. The British raised no objection to this.

PRINCIPLE (9). A detailed discussion took place on this, which states:

> Tolerances should be assigned to component features for position, concentricity, symmetry, alignment, squareness, and parallelism, when the control of these elements is important for correct functioning and, or alternatively, correct assembly.

The American delegates proposed adding to this principle the phrase "keeping in mind that the drawing should not be unduly complicated and hard to read." The British raised no objection to this but took the attitude that other suitable methods, such as the use of symbols or standard notes, could be adopted for expressing tolerances on position, concentricity, etc., without complicating the drawings.

No Agreement on Position Gages

The British delegates disagreed with the American view that position gages were generally dangerous and were not to be recommended. They stated that such gages, when properly designed, provided a reliable method of insuring assembly between mating parts involving positional dimensions. The proposed British system of tolerancing such dimensions on component drawings was designed, primarily, with that object in view. It also provided for exceptional cases where inspection involved the more difficult operation of direct measurement of positional errors.

The British were in sympathy with the American comment that lengthy calculations such as those given in Gladman's paper in connection with position gages should, if possible, be relegated to an appendix and only the final formula be given in the body of the text of any manual that may be prepared.

PRINCIPLE (10) reads:

> Methods of indicating dimensions and tolerances of composite work should be formulated on the basis of simple manufacturing and inspection methods.

This principle was accepted without comment by the American delegates.

Some discussion followed on the question of the desirability, or otherwise, of tolerancing angular dimensions where they relate to mating surfaces. The British considered that tolerances for angular dimensions should not generally be recommended and should be avoided as much as possible because of the difficulties of control. They preferred to tolerance the associated linear dimensions so as to establish a parallel band of metal tolerance within which the angular dimensions might be permitted to vary. The American delegates agreed to consider this point, but they anticipated there would be difficulty in getting the British recommendation adopted in the United States.

At the opening of the second session on the subject it was agreed that it would be inappropriate to discuss additional details given in the set of papers submitted by the British until the other two countries had had time to study these papers in committee. The British explained that their folder of papers was intended to convey the latest views of their Inter-Services committee and that, while they still adhered to the fundametals as set out in Gladman's paper, the committee's work during the past twelve months had resulted in a number of important developments and an expansion of details on which they would welcome American and Canadian opinion as soon as possible.

During the ensuing discussion the Canadian delegates, in particular, stressed the importance of developing this subject of drawing practice on an industrial peacetime basis. They considered that if industry were educated in peacetime in the production and use of well-prepared drawings, it would make for easy transition to wartime manufacture if this ever became necessary.

It was generally agreed that no information as to tolerances and required accuracy should be omitted from drawings, but opinions differed as to whether such information should be given entirely by notes or whether symbols such as those suggested in the Gladman paper, and indicated in *Fig.* 2, might be used to replace the more lengthy and complicated form of notes. In this connection it was mentioned that drawing symbols had latterly been instituted successfully in relation to welding practice. The British delegates stated that no difficulty had been experienced in educating draftsmen in the application of symbols to drawings and they were of the opinion that symbols provided convenient means for condensing notes. The meanings of the symbols they proposed were explained in the "Standard Drawing Vocabulary for the Interpretation of the Dimensioning and Tolerancing of Engineering Drawings", Sheet D. C. 96, this being another of the British papers prepared for the conference.

The conference expressed the need for a universal system of nomenclature and definitions relating to drawing practice, limits and fits, etc. It was agreed that the American and Canadian delegates would review the comprehensive set of definitions prepared by the British on this subject.

Third Angle Projection?

Reference was made by the American delegates to the desirability of unifying the method of projecting views on drawings, the third angle method being used in America as against the first angle in Great Britain. The British delegates stated that they were alive to this point and that it was being considered by the British Standards Institution.

The American delegates referred to a textbook on interchangeable manufacture written some years ago by Earle Buckingham which deals with some aspects of the dimensioning and tolerancing of drawings. The British delegates mentioned that they knew of this book and had studied it with interest.

It was recommended, in conclusion, that the standards bodies in the three countries should cooperate closely in establishing a standard code for the dimensioning and tolerancing of industrial drawings acceptable to the three countries concerned.

Designing Computing Mechanisms

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Part VII—Stepping Followups

FOLLOWUPS considered previously have all involved drives in which the speed was smoothly and continuously variable from maximum to minimum. However, there is another class of followup, widely used in computing mechanisms, in which the drive unit is either fully energized in one direction or the other, or is off altogether. Such a followup tends to follow the controlling quantity by periodic steps, hence will normally have a characteristic quite different from the continuous type. Nevertheless modifications can be added which will make the stepping types approach continuous action, and in their proper sphere they are entirely satisfactory.

A drive frequently used for these followups is a two-wire reversible motor. One type is the so-called split-field series motor (*Fig.* 53*a*), suitable for either alternating or direct current. This motor has two series field windings, connected in opposite sense, so that the motor reverses as the movable followup control contactor shifts from one fixed contact to the other. Another type is the single-phase capacitor induction motor (*Fig.* 53*b*). This motor has two windings spaced 90 electrical degrees apart. When the line connection is made to contact 1, winding 1 is energized directly, while winding 2 is energized through the capacitor. This makes the current in winding 2 lead that in winding 1, producing a rotating component of flux and causing the rotor to turn. When the line connection is to contact 2, this rotating component revolves in the opposite direction, reversing the motor. Of course any motor capable of reversal can be employed, but these two can be controlled by a single selective contactor and are therefore much used.

The followup control consists simply of a movable contactor operating between two fixed contacts, the separation being as small as possible consistent with good operation. The movable contactor is driven by the control line from the followup differential through an accumulator, *Fig.* 54, which is simply an intermittent drive, often integral with the followup control. The accumulator is essential with this type of control, inasmuch as the range of travel of the movable contact is limited to the airgap separation of the contacts, while the control line, representing the difference between the input and output functions, may be required to have a much greater range. For example, the supply to the motor might be turned off or fail while the input was changing, or the input might be moving faster than the motor could follow.

The accumulator is designed so that at the synchronizing

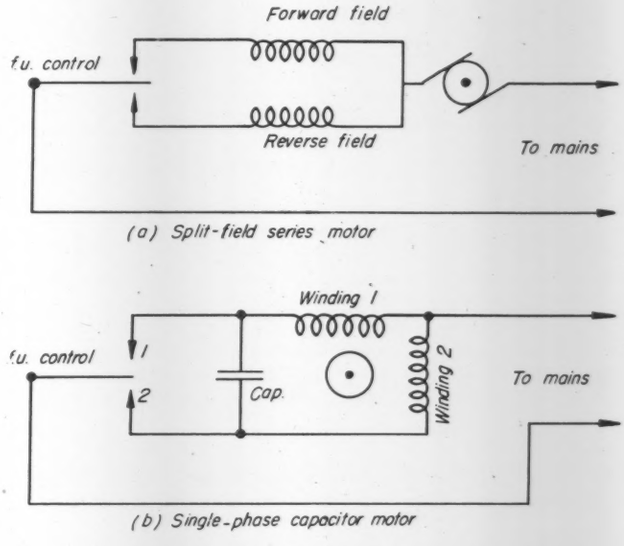


Fig. 53—Two types of stepping followup motors. Followup control is driven from followup differential

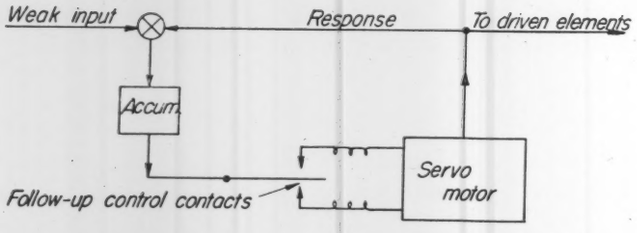


Fig. 54—Stepping followup mechanism, showing how movable contactor is driven through an accumulator

point the control line can positively shift the contactor from one fixed contact to the other, but not turn it any further. One satisfactory arrangement is to move the contactor by means of a cam acting against a spring-loaded follower. After the contactor strikes the fixed contact, further movement of the cam merely lifts the follower out of the notch. If additional accumulation is required to prevent loss of calibration when the input and output quantities have their greatest possible separation, a Geneva-type intermittent drive can also be included in the control line. It might be mentioned here that some form of accumulator may be necessary even with the continuous type of servo described previously, when the speed control range is less than the maximum possible separation of the input and output quantities.

Why There Is Tendency To Oscillate

It will be evident that the stepping followup has an inherent tendency to oscillate. Thus if it is assumed that the input and output are initially out of synchronism, the control contactor will lie against that fixed contact which causes the motor to drive toward synchronism. The output will overtake the input and reach the position of synchronism with an excess of speed, which will cause the motor to coast past the point and engage the opposite contact. This will "plug" the motor and slow it down, eventually stopping and reversing it. It will then approach synchronism from the opposite direction and again overhaul.

Whether these oscillations will diminish, remain constant, or increase in amplitude depends upon a number of factors among which are the inertia of the rotor and connected parts, the nature and extent of the friction load, and the torque-speed characteristic of the motor, both in the forward and "plugging" directions. The series-type motor is superior to the induction motor in this last respect, because its plugging torque at a given speed is greater than its forward torque at the same speed. Hence it will "come off" the contact on each successive swing with less speed than it "hits." The induction motor, on the other hand, has lower plugging than forward torques, and therefore will tend to build up oscillations. However, the induction motor is simpler and requires no brushes, so it justifies more extensive damping means.

It is clear that if the inertia were small enough, the friction load great enough, and the contact airgap wide enough, the motor would coast to a stop before reaching the opposite contact. Such a method of preventing oscillation is not often practicable, since adding friction decreases the ability of the motor to do useful work and also reduces its accelerating power, while increasing the airgap decreases its positional accuracy; likewise the inertia cannot be reduced indefinitely, particularly if most of it is due to connected load. The method will sometimes work satisfactorily with series motors, but is practically impossible with the induction type. Consequently some additional damping means is required in most cases. Among the types frequently used are the Lanchester damper, anticipation damping, and contact vibration.

Damping by Slipping Friction

LANCHESTER DAMPER: This device, widely used for damping torsional vibration, consists of an inertia weight mounted on the shaft extension of the motor, but free to rotate independently. It is, however, in frictional contact with a disk fastened to the shaft, the necessary friction being provided either by a viscous drag between the two, or by cork or leather faces kept in contact by spring pressure. Under constant speed conditions the disk and weight rotate together and the only effect is an increase in inertia. Under conditions of high acceleration, such as would occur with oscillation, the weight slips and absorbs energy from the system, thus exerting a damping effect. The conditions for optimum energy absorption are given by Prof. DenHartog[21]. Modifications of the Lanchester damper for servo use have been the subject of several recent patents[22].

ANTICIPATION DAMPING: As mentioned earlier, no oscillation will take place if the motor stops before the control reaches the reversing contact. To accomplish this the supply to the motor must be opened sufficiently in advance to allow the motor time to coast to a stop just as the movable contactor reaches a point midway between the two fixed contacts. The distance the motor will coast after power interruption is obviously a function of the speed of the motor at that instant, as well as the inertia of the system and the amount of friction load. The latter two factors are usually substantially constant, so the coasting

21. J. P. DenHartog—*Mechanical Vibrations*, 1940, Pages 124-126 and 255-258.
22. E.g., U. S. Patent 2,042,280.

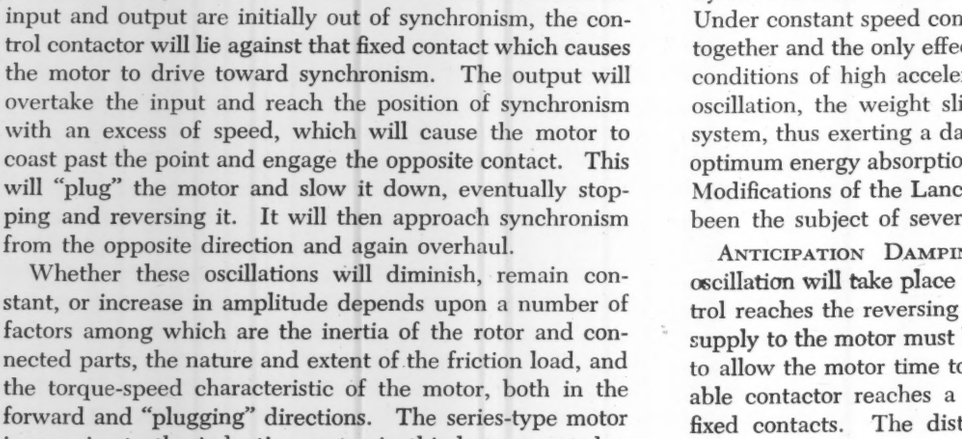


Fig. 55—Anticipation damping for stepping followup, providing a lead proportional to motor speed

distance is an increasing function of motor speed.

To provide the required anticipation, a "lead" proportional to motor speed is added to the response input by a second differential, *D*-2 in *Fig.* 55, thereby causing the movable contactor to come off the fixed contact earlier by an amount proportional to the speed. If the anticipation coefficient is correct the movable contactor will never reach the other fixed contact, for as the motor slows down the lead will diminish in proportion, and should just cancel the movement due to the coasting of the motor. In fact a slight over-anticipation is desirable, so that the movable contactor will return to the original fixed contact for additional "nudges" before reaching the synchronized position.

The anticipation is not necessarily introduced by a differential gear, as shown in *Fig.* 55. In some cases the fixed contacts are differentially mounted, so that they are moved back and forth by the anticipation input, producing the same result.

Anticipation can be obtained by any suitable tachometer or speed-measuring device driven by the servomotor. Note that it must show *direction* of rotation as well as speed. Viscous drag types are satisfactory, such as spring-opposed hydraulic or magnetic drag cups.

Reflection will show that the arrangement of *Fig.* 55 will introduce a steady state velocity lag. When the control is synchronized the output of *D*-1 is zero, or:

$$x-\left(y+\frac{1}{K}\frac{dy}{dt}\right)=0$$

Where $1/K$ is the anticipation coefficient. The anticipation coefficient is represented in the form $1/K$ in order to make K correspond with the control sensitivity factor used in the previous analyses. The term $1/K$ has the dimensions of time. The previous equation may be written

$$y=x-\frac{1}{K}\frac{dy}{dt} \qquad (26)$$

This steady state error sometimes can be eliminated by having the tach driven by the control line, but as this imposes the tach torque on the weak input line it may not always be feasible. Another scheme is to connect the driven elements to the left-hand (response) side of *D*-2, but this puts the load torque on the tach output, which may be equally undesirable.

CONTACT VIBRATION: With this scheme the "fixed contacts" are not truly fixed, but are rapidly vibrated by suitable means about a fixed central position. The same effect also can be obtained by superimposing a vibratory rotation on the movable contactor. The amplitude of vibration and the airgap spacing is greater than the preceding types "central," the contactor alternately engages each fixed contact equally. This induces a forced oscillation of the motor, but if the frequency of vibration is made high in comparison with the natural frequency of the servo system, this forced oscillation can be reduced to an almost imperceptible quivering. A small, high-freqency quiver is often highly desirable since it reduces the effects of backlash and static friction. If, now, the input begins to change, the movable contactor must take up an average position closer to one of the fixed contacts, so as to lengthen the dwell on one side and cause the motor to turn. The higher the speed, the longer must be the dwell and the more the control input must turn. Thus a species of velocity lag is introduced into the system, and herein lies its damping effect. This type of control gives rise to some *load lag* also, since the length of dwell must increase with the load, and the airgap spacing is greater than the preceding types to take care of the amplitude of vibration. The control sensitivity, which represents the change in speed corresponding to unit difference in x and y, is affected by the vibration amplitude and airgap spacing as well as by the actual gear ratios. Thus further adjustment of the amount of damping is possible even after a design is constructed.

The operating characteristics of impulse-actuated d-c motors for varying contact frequency and duration are developed in a paper by Blaufuss[23]. Although this paper refers specifically to d-c shunt motors, the analysis can

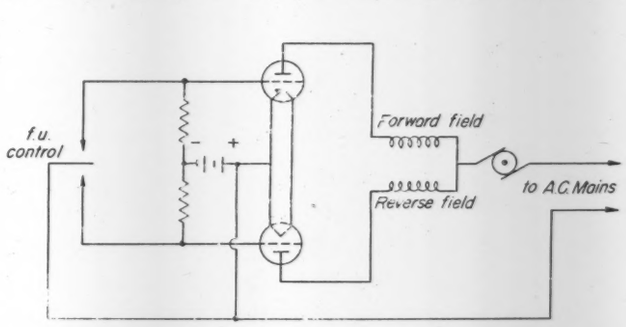


Fig. 56—Stepping followup with electronic relay for controlling the split-field series motor

be extended to other types. A significant point brought out is that regulation by means of armature current interruption is equivalent to inserting resistance in series with the armature, but with the important difference that the resulting I^2R loss is *dissipated in the winding.* This fact should be borne in mind when designing or choosing motors for stepping followups, as the heating may be considerable at low speeds with high torques.

Of the three methods of damping considered, anticipation damping generally produces the smoothest control, but is the most complex mechanically. Contact vibration is less satisfactory as regards smoothness, and has considerable load lag in addition to velocity lag; however it is simpler to apply. The Lanchester damper is least satisfactory, since it is not "dead beat" and is apt to be "jerky" under rapidly changing speeds, but it is simple mechanically and produces no steady state velocity lag. Sometimes the Lanchester damper is combined with contact vibration.

STEPPING FOLLOWUPS FOR HIGHER POWER: The servos just described are limited to powers that can be controlled by circuit interruption in the main supply, or about 1/8-hp at the most. However, this system can be extended to higher powers by various relaying methods, among which are the following:

MAGNETIC CLUTCH: This scheme employs two electromagnetic clutches driven from a common mechanical source, having their outputs geared to the driven elements in opposition. Their windings are selectively controlled by the followup control contacts in conventional fashion, so that the direction of rotation of the driven elements is

23. K. Blaufuss — "Drehzahlregelung von Gleichstrommotoren durch Stromstrosse", *Archiv fur Electrotechnik,* Vol. 34, No. 10, 1940, Pages 581-590.

determined by whichever fixed contact is engaged, the output disk of the clutch not energized then merely turning idly in the reverse direction. The control contacts thus have to interrupt merely the current through the magnet windings, representing only a fraction of the actual power controlled. The various damping means already described have all been used with satisfactory results. These clutches are usually made in twin units, and where a number of followups are employed in an instrument, they are piled up in tandem on a common drive shaft, thus securing a compact design.

Since the clutch, in effect, regulates the output speed by slipping, there is a loss by friction proportional to the product of the load torque and the slip. This loss appears as heat in the driving faces, and under conditions of low speed and high torque may represent considerable energy. Account of this must be taken in the design of the clutch, special provision being made for heat dissipation where necessary. One horsepower appears to be about the top limit with air cooling.

REPRINTS

In response to many demands for reprints of the entire seven-part series of articles on "Designing Computing Mechanisms," these will be made available, at a cost of $1.00 per copy postpaid. They may be obtained from Readers Service Dept., MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio*

* Ohio orders should include sales tax.

ELECTRONIC CONTROL: An electronic tube can be used as a relay for controlling the split-field series motor in the manner indicated in *Fig.* 56. With this scheme the contacts carry only the small current which flows through the grid resistor when the grid bias is shorted. The tubes are preferably the gaseous (Thyratron) type, in order to obtain a low voltage drop. Such tubes require the use of an a-c plate supply to retain grid control, for control is lost as soon as the discharge commences. By using alternating current, discharge takes place only during positive half-cycles, due to the unilateral or rectifying property of the device; thus control is restored within a half-cycle after the application of negative grid bias. Note that the mention made earlier about I^2R dissipation in the windings of impulse-actuated motors applies with equal force to this case. The mode of control is the same as before, the electron tube acting only as a relay. Consequently the motor must be designed to dissipate safely the heating produced at low-speed high-torque conditions. The methods of damping described earlier can also be applied here.

MAXSON ELECTRICAL DRIVE: This recently developed system is shown in its basic schematic form in *Fig.* 57. A motor and generator are used in a manner suggestive of the Ward-Leonard system, but the generator field is controlled by step contacts. Special damping or feed-back circuits have been devised which cause the contacts to make and break rapidly, so that under steady state conditions the field strength varies only slightly about a mean value. Thus all the advantages of the variable-voltage continuous system are obtained, plus the high sensitivity of contact control. Full field strength is almost immediately obtainable for rapid acceleration. The parasitic I^2R loss at low-speed high-torque conditions mentioned in connection with the previous stepping followups is not present in the Maxson drive, the applied emf varying with speed.

SERVOMECHANISMS IN GENERAL: To the casual reader it might seem that undue space has been given to servos in a series supposedly devoted to computing mechanisms. Actually the subject has been treated in too cursory a manner. Servos are so intimately connected with the operation of most continuous computers that in nearly all cases their success or failure depends upon the design and performance of their servo systems. It is clear that many of the computing mechanisms described herein are not capable of exerting more torque than is required for driving a few dials and counters, or the inputs to similar light mechanism. If any considerable load is to be driven, such as a synchro transmission system, servos are essential. Also some computing processes (such as one of the division methods) utilize "feedback" schemes requiring servos. The following additional references will be found instructive to the servo designer:

H. K. Weiss—"Constant Speed Control Theory" *Journal of the Aeronautical Sciences*, Vol. 6, No. 4, Pages 147-152.

C. S. Draper and G. V. Schliestett—"General Principles of Instrument Analysis", *M. I. T. Paper*, 1939.

C. R. Hanna, K. A. Oplinger, S. J. Mikina—"Recent Developments in Speed Regulation", *AIEE Transactions*, Vol. 59, 1940, Pages 692-700.

C. R. Hanna, W. O. Osbon, R. A. Hartley—"Tracer-Controlled Position Regulator for Propeller Milling Machine", *AIEE Transactions*, Vol. 64, 1945, Pages 201-205.

E. S. Smith—*Automatic Control Engineering*, McGraw-Hill Book Co., 1944. Contains fine bibliography.

L. A. MacColl—*Fundamental Theory of Servomechanisms*, D. Van Nostrand Co. Inc., New York, 1945.

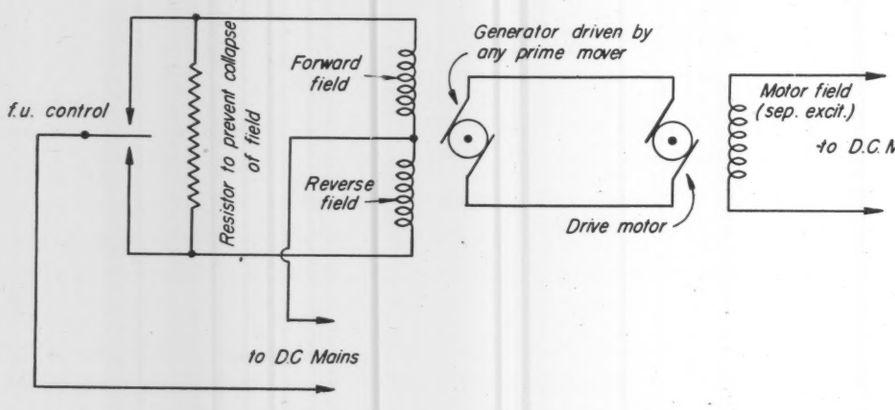


Fig. 57—Followup using Maxson drive, with damper circuits omitted. System employs motor-generator with generator field controlled by step contacts

Life Quality Predictions by Statistical Methods

By Enoch B. Ferrell
Bell Telephone Laboratories Inc.

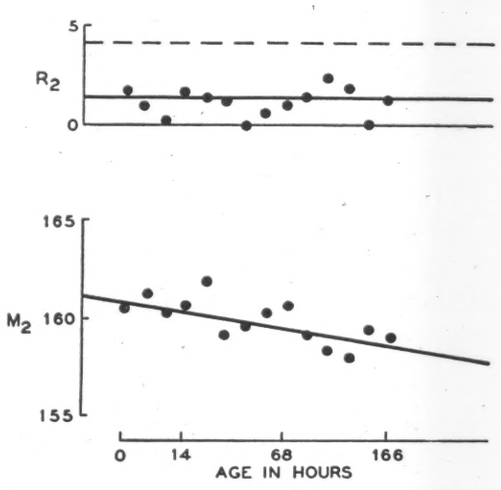


Fig. 1—Range and midrange trend medians computed for groups of 2 on a relay test for operate or pull-up current

LIFE tests on a new design should be so planned that the methods of statistical quality control may be used to separate assignable from random causes for variation during life. The user wants to know: How often will I have to replace this piece of equipment? The manufacturer or his development man wants to know: How long a life can we guarantee to our customer?

These questions show that we are not interested in how long a particular gadget that was made last month did run before failure. We are interested only in predicting how long many gadgets, that will be made next month, will run before failure. Restating the questions: First, can we make reliable predictions about the life of our gadget? Second, if we can predict, what are the expected average and dispersion of the life or, if we cannot predict reliably, why not, and what can we do about it? There is another question: Can a design change be made that will increase the life or reduce the cost?

One of the fundamental requirements for reliable predictions is that they be based on measurements of representative samples of uniform manufacture. In the tests to be discussed, the equipment studied is a new type of relay which was in the midst of development and preparation for manufacture.

For the life test, samples were taken from lots which were in statistical control. The samples were believed to be representative of stable manufacturing processes. Each relay was arranged to operate and release in a work circuit 60 times per second. At stated intervals, inspection would consist of accurate measurements of two principle characteristics: The current at which the relay will operate or pull up, and the current at which it will release or drop out.

TABLE I

Operate Current Data for Life Test

Date	Age	Observations				Repetition° R_4	Repetition° M_4	Group† R_2	Group† M_2
713	0	159.8	160.1	159.9	160.1	.3	160.0		
806	0	160.3	160.2	163.8	160.0	3.8	161.9	1.9	160.9
	1	162.0	161.9	162.0	162.0	.1	162.0		
807	2	161.9	160.2	161.8	160.0	1.9	161.0	1.0	161.5
	5	160.1	160.0	160.8	160.1	.8	160.4		
	8	160.4	159.8	160.5	159.9	.7	160.2	.2	160.3
809	11	160.2	159.7	160.2	159.8	.5	160.0		
	14	162.0	161.7	162.0	161.9	.3	161.9	1.9	160.9
810	17	161.9	161.0	161.9	161.5	.9	161.5		
	20	162.5	162.4	163.1	162.4	.7	162.7	1.2	162.1
811	23	159.9	160.0	159.9	159.8	.2	159.8		
	26	158.3	159.0	158.8	159.0	.7	158.7	1.1	159.2
812	33	158.0	160.0	160.5	160.0	1.5	159.8		
813	40	159.8	159.9	159.8	159.9	.1	159.8	.0	159.8
	47	160.0	160.0	160.0	160.0	.0	160.0		
814	54	161.0	160.2	161.0	160.2	.8	160.6	.6	160.3
816	61	160.0	160.2	160.5	160.5	.5	160.3		
	68	161.0	161.8	161.5	161.5	.8	161.4	1.1	160.8
817	75	160.5	159.8	161.0	159.9	1.2	160.4		
818	82	158.5	158.5	159.0	158.5	.5	158.7	1.7	159.6
Process Standard§		Average				.24		1.33	
		Limits				0		0	
						.55		4.35	

°Range of deviation and midrange for four observations.
†Range and midrange from repetition data in groups of 2.
§Based on tests of several relays.

About 20 inspections were made during the first ten days. If the relays failed in less than ten days and enough data had not been obtained, we could start over without too much loss; but two inspections per day were too ex-

From a paper presented at the winter meeting of the American Institute of Electrical Engineers.

pensive. Moreover, it would give more data than we had time to study. So, after an initial period, the relays would be inspected whenever their age had increased about 10 per cent.

For measuring the operate and release currents a measuring set that minimizes the influence of the operator or the surroundings was utilized. The relay is connected to the measuring set and the operating switch is thrown. The set automatically increases the current in the relay slowly until it operates and then displays the value of the operate current on a meter for several seconds. The operator merely throws the switch, reads the meter, and writes down the reading. The meter has a 6-inch scale and is read to 1 or 2 parts in 1500.

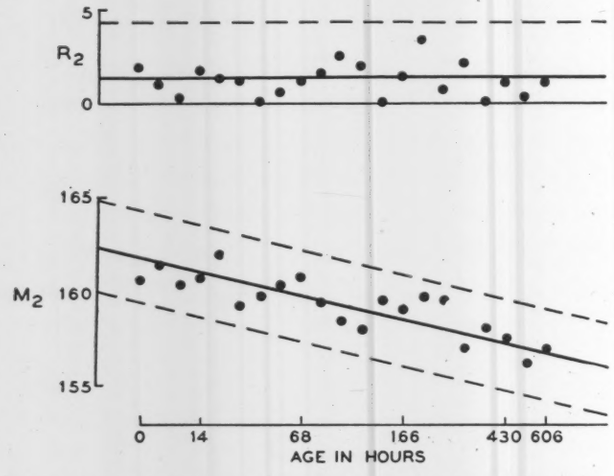


Fig. 2—Control chart of group range and midrange for current to operate or pull up relay

TABLE I shows the method of recording the data for operate current. Release current is recorded similarly. At each inspection, four observations of operate current are made and recorded on one line. After them are recorded the range and midrange of these four repetitive observations. We might call them repetition range and repetition midrange. When two inspections have been made, the two repetition midranges are treated as new data and the range and midrange are computed for the group of 2.

In this work ranges and midranges were used in preference to standard deviations and averages. The ranges and midranges are easier to compute and the method of computing them is exactly the same in all details, whether the sample size is 2 or 6. This simplifies the instructions to the technical assistants and speeds up their work. Since these statistics depend only on the extreme observations, they may be a little more useful in detecting trouble.

Control chart coefficients are published for ranges. For a sample size of 2, the midrange and average are, of course, the same. For small samples, in general, it may be that the midranges and the averages, with their statistical fluctuations, are enough alike to permit their interchange in an analysis of this type.

Repetition ranges represent variations in the relay, and also variations due to meter reading, building vibration and the like. We would expect this dispersion to be constant, both within and among the relays. The average repetition range, and control limits based on it, were computed by lumping together several inspections on several relays. They are shown at the bottom of TABLE I. The repetition ranges here are badly out of control. This was at the beginning of the tests. We convinced ourselves that the trouble was due to operator inexperience and that it was not seriously affecting the experiment. The repetition ranges did later come into fairly good control.

The group ranges represent the variations mentioned above, plus the variations caused by handling the relays, drifts in the measuring set and the like, plus any variation due to real aging in the relay. They show, on the whole, very good control. They indicate that the effect of aging between inspections is small as compared to what we might call the effect of handling. We do not expect the repetition midranges to stay within limits based on repetition ranges, because an additional cause for variation, the handling, is interposed between inspections.

We might have expected the group midranges to be in control within limits based on group ranges. They were not. They showed definite trends. Here was a real indication of aging. This aging trend was evaluated as follows:

After 14 group midranges had been plotted for a relay, a median line was drawn as in *Fig.* 1. It was a sloping median line, placed at such a height that half the points were above it and half below. It was placed at such a slope that the number of runs,* above and below, was a maximum.

The use of this line and the method of placing it may need some explanation. If we believed that there existed some functional relation between operate current and age, we could compute the current for each age on the basis of that functional relation, subtract the computed current from the observed current, and get a set of remainders.

TABLE II

Summary of Outages

Number of Relays	Identification	Action
All	General trend	New spring
9	Initial	Pre-age relay
10	Measuring set	Repair set
14	Spring stabilization	New spring
6	Temperature	Redesign measuring set
4	Faulty test	Start over
3	Faulty manufacture	Modify process
3	Heavy load	Study load circuits
10*	Unexplained	No action

*Number of individual points outside control limits.

These remainders would represent the departure of our experience from the assumed functional relation. We could study these remainders statistically. If we found, in the remainders, evidence of cycles or trends, then we would say there are functional relations other than that already considered. If we found what the statistician calls "no evidence of lack of control", then we would think there is no functional relation between the remainders and the age. Our confidence in this belief would depend

*W. A. Shewhart—"Contributions of Statistics to the Science of Engineering," University of Pennsylvania Bicentennial Conference, Volume on *Fluid Mechanics and Statistics,* 1941, Pages 97-124.

on the thoroughness of our search for lack of control.

We have done just this, but have done it graphically. We have used, in effect, a graphical transformation of coordinates. The functional relation that was used is defined by the time scale, the position, the slope and the straightness of the line. Because we have an unusual time scale, we are testing an unusual functional relation. There may be a better or more logical functional relation. The best of statistical control in the remainders would not prove that this functional relation is "the right one," but merely that, empirically, it is a good approximation in the region studied.

Median Was Chosen for Convenience

In our case, the time scale and straightness of the line were purely matters of convenience. They fixed the form of a two-parameter function whose two parameters, the height and slope of the line, could be easily chosen. The choice of height rests on our desire to have the central value of the remainders after transformation equal to zero. It is somewhat easier to use the median as the measure of central value than some of the others. So, we placed the line with half the points above and half below.

The slope of the line was chosen in an effort to make one of the simplest tests for control show no assignable causes. This test is the study of runs* above and below the median. A run is a sequence of consecutive points on the same side of the line. The expected number of runs is roughly half the number of points, actually $(n+2)/2$. This makes the expected average length of run about 2. The presence of longer and fewer runs tends to indicate the presence of trends. We would like to include any such trends in our functional relation and that would eliminate long runs. The presence of shorter and more numerous runs, which means many runs of length one, indicates a cyclic variation with a period of 2. That would not affect our choice of slope to represent a long trend. So, we have used that slope which gave the greatest number of runs.

These ideas explain, whether or not they justify, our method of drawing this line which, because of its characteristics, we call a median line. Because this is an extension of the original concept of the median of a lumped or unordered distribution to the concept of a median of an ordered array, we have qualified it and called it a sloping median. Perhaps trend-median would be a better name.

These sloping median lines were drawn for eight relays, with encouraging results. The number of runs was fairly close to the expected number. The slopes were in good agreement. To show this, we measured and averaged these slopes and redrew the plotted medians so that all had this average slope. Since the manufacturing variations among relays is greater than any of the variations discussed here, each line was drawn at a height to make it the median for that one relay.

To further study the singleness of this assignable cause for variation, control limits were placed above and below these median lines at spacings derived in the usual manner from the average group range. *Fig.* 2 shows the complete control chart for group range and midrange. This chart goes up to 600 hours age. The determination of slopes and control limits was made on eight relays at an age of 166 hours. The control chart has held good through an extrapolation by a factor of nearly 4 in age.

Aging trend up to 5000 hours is shown in *Fig.* 3. The upper curve is for operate current, the lower for release current. Each point is the average for ten relays. It represents four repetitive readings, at each of two inspections of each of ten relays—a total of 80 observations, averaged in each point. The slope of the median line for operate current is the same as that determined at an age of 166 hours. The last few points are significantly above the line. It may be that the whole aging trend is caused by change in a repeatedly overstressed spring, and that this flattening of the curve shows approach to a new equilibrium. The continued slope of the release current seems to disagree with this. We do not know.

The median line for release current as drawn at 166 hours was steeper. Only 14 points were available then, so it may have been a "small sample" effect. It is more likely to be related to erratic behavior sometimes encountered in the first 20 hours. The slope of the release line shown in *Fig.* 3 is the same as that of the operate line.

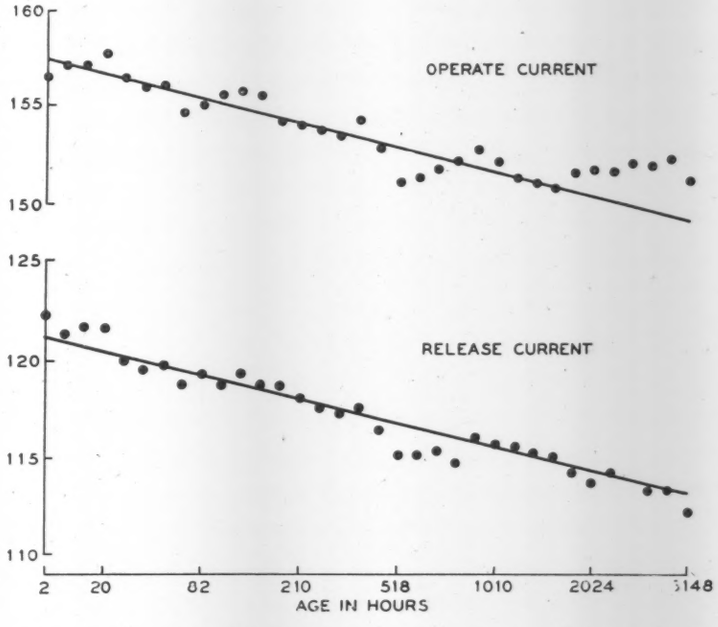


Fig 3—Operate and release currents average of ten relays showing trend up to 5000 hours

Control limits have not been drawn on the ten relay average curves of *Fig.* 3. If they were, they would be spaced less than a third as far apart as in *Fig.* 2, and many outages would be observed. We think the explanation is this: In addition to the dispersion due to what we called "handling," there is an effect of temperature on the measuring set. This is less than the "handling"

effect and, in single relays, is concealed by it. When ten relays are averaged, the dispersion due to handling is reduced. But, because the relays were started into their tests in a few groups and measured together later as a group on a cold day or a hot day, averaging does not reduce the temperature effect. This now shows up to give outages on limits set by the "handling" dispersion. This same temperature effect probably accounts for some of the long runs observed in the individual curves.

Causes for Outages

TABLE II is a summary of outages observed in tests on 28 relays. At the time of preparing this summary, some had been run to destruction, others had been run a few hundred hours without failure, and others a few thousand hours.

Nine relays showed outages in the first 20 hours, mainly high values. If the chart is replotted on other time scales, some of these outages disappear and others appear. This may not be important. We think these early outages indicate a real trouble and contributed to our bad guess on the aging rate for release current at 166 hours.

Ten relays showed outages all at about the same time when the measuring set went bad. That trouble was corrected. It was found that the calibration of the set had been in error by about 2 per cent. In plotting these charts, the early points have been corrected by that amount. Fourteen relays showed outages by having high operating current after about 2000 hours. This may be the aging of the spring as mentioned before. There were six outages that were traced to the temperature effects in the measuring set already mentioned.

Seven relays were removed from the life test without giving information about life. For one pair, the circuit had been wired wrong and the relays were worn out in 600 hours. The fault was discovered at about 40 hours, but the test was continued just to see what happened. For another pair, the circuit broke down and damaged the relays. Another pair aged very rapidly and was found to have been improperly made. The seventh failed suddenly at 2690 hours and was found to have a foreign particle in it that had worked into the hinge. This also was faulty manufacture. These seven told us nothing about normal relays.

Dependable Life for Heavy Loads

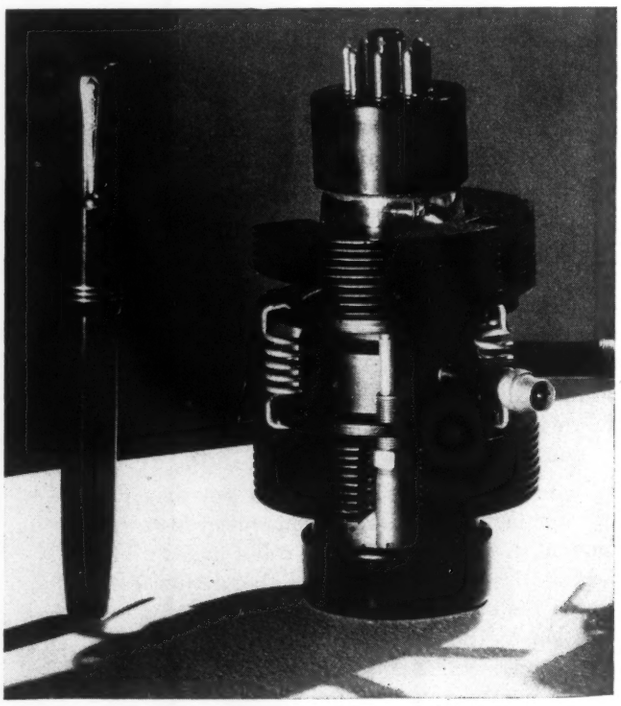
Three relays operated at heavier loads failed. The ten relays used to plot the average aging curve were worked at loads of 20 watts or less. One of these three relays was worked at 200 watts. It shows a normal aging curve, but failed at 2645 hours. The other two were worked at 300 watts. They showed abnormal aging and failed at 490 hours. There was some question as to the manufacture of these two since they were taken from a lot with a large number of known defectives. From this meager information, we are tempted to guess that at these heavy loads the dependable life is about 500 hours.

In addition to these outages for which causes have been assigned, there were ten outages in over 2000 points for which the cause is unknown. With 3-sigma limits, the expected number of outages is six, and the sampling fluctuations might take this up to 13. It is possible that these ten outages are really due to random fluctuation.

From these tests we can promise a useful life of over 5000 hours at 60 operations per second with a load of 20 watts or less in a properly designed circuit. At 200 or 300 watts, we have some indication of a life of a few hundred hours. This can be predicted from the data related to the random causes. Data related to the assignable causes have led to improvements in design, manufacturing process, and testing process, and may lead to improvements in methods of use.

Generates Radar Frequencies

GENERATING superhigh frequencies—from a few hundred million to a few thousand million cycles per second—for radar use the klystron illustrated was conceived by two men while working at Stanford University. Electrons from a cathode are hurled through a cavity toward a reflector. Variations in velocity produced in the cavity as the electrons travel back and forth result in an electronic current,



producing ultrahigh frequency power in the cavity.

Conventional design did not permit electrons to strike the reflector. Instead, before they reached it, they were turned back toward the cavity. The efficiency was only about one per cent. Westinghouse engineers coated the reflector with a secondary emitter and found that the electrons striking it gave the effect of secondary emission, enabling the tube to deliver more power because of the high current. Furthermore the efficiency was tripled and the power absorption increased eight times, resulting in 24 times as much power output.

MACHINE *Editorial* DESIGN

Why Not Incentive Bonuses?

WITH the answer to the problem of labor unrest still an interminable question mark—at least at the time this is written—it might be recalled that wage incentive systems have furnished the solution in many cases to the establishment and maintenance of satisfactory labor-management relations. It has been proved entirely possible not only to increase the wages of workers through the adoption of incentives but also to increase productivity and at the same time reduce costs.

An average increase of 40 per cent in production per manhour, according to War Labor Board figures, was effected during the war in the first 90 days of operation of incentive systems in a number of plants employing approximately a million workers. During the same period wages rose on the average 15 to 20 per cent and costs were reduced 10 to 15.

Even though the vital urge to win the war was present during recent years, and national production in general rose considerably through employment of more workers and the development of higher-speed and more specialized machines, worker efficiency decreased on the average from 10 to 20 per cent in plants employing day-wage rate systems. At the Ford Motor Co., as brought out by Henry Ford II in his address at the annual meeting of the SAE, productivity per worker declined more than 34 per cent during the war period.

To offset this decline in the production rate of the individual worker—be the cause what it may—it is apparent that any steps that can be taken to alleviate the situation should be given all the consideration they may deserve. At the same time it is evident that the engineer responsible for design of machines should continue to utilize his skill to the utmost in developing equipment capable of higher mechanical production.

While some of the labor unions look with disfavor on individual incentive systems, the plant-wide incentive, or bonus, payable at the end of the year or at intermediate periods on the basis of production and sales over the same period, might well prove to be the solution to much of the current strife. Arrangements of this nature have been in effect in many manufacturing plants for years, with completely satisfactory results.

In the days ahead three primary factors will govern progress and well-being: High wages, maximum production and low costs. Incentive bonus systems could go far toward establishing all three. Does it not seem they should be given a fair and extensive trial?

L. E. Jermy

Outstanding Designs

VOYAGER 150

Bringing increased comfort and pleasure to flying, this new Stinson personal airplane is insulated and soundproofed with engine noises muffled to a point where normal conversations are possible throughout the cabin. Owing to effective elimination of noise and improved radio equipment, an overhead dome-type speaker can be utilized in place of the usual headphones. Both aircraft (200 to 410 kilocycles) and commercial broadcast (550 to 1500 kilocycles) bands are provided in the radio equipment for maximum enjoyment. Transmitter is tuneable in the range from 2600 to 7000 kilocycles. Headphones, if desired, can be plugged into a convenient jack located on the instrument panel.

Designed to seat four passengers comfortably, the plane, with a wing span of 34 feet and fuselage length of 23½ feet, weighs 1206 pounds empty. Powered by a 150-horsepower Franklin engine, it has a cruising speed of 125 and a maximum speed of 133 miles per hour. With a fuel capacity of 40 gallons the cruising range is 500 miles. Service ceiling is 14,000 feet. The wing, slotted and constructed with a moderate dihedral, has large landing flaps enabling the plane to land in comparatively small fields. It requires a landing run of only 230 feet at sea level. In order to become airborne at sea level, a 560-foot runway is necessary.

With mufflers on the exhaust, motor sounds are softened and spread, giving the engine a smooth, pleasant hum rather than the ordinary pinging and banging noise. The silenced engine is a development intended to overcome the objections to airplane noise by people living adjacent to airports.

ARC WELDER

Special feature of this new transformer type arc welder manufactured by the Lincoln Electric Co. is its arc striking characteristic. Construction is such that striking currents up to ten times normal value are obtained. A relay adds the striking current to the ordinary welding current for a fraction of a second after an electrode is touched to the work.

Transformer used is of the two-winding type with the primary fully insulated from the secondary by mica and glass. All wires are glass covered and treated with synthetic baking varnish to permit high overload temperatures. Control is obtained by varying the air gap in the reactor iron using a rotating section which can be turned through 90 degrees. Continuous adjustment and quiet operation is achieved by means of a roller chain drive to the hand control. Built for 230-volt, single-phase power, current range is from 20 amperes at 20 volts to 180 amperes at 25 volts for electrodes ranging from $\frac{1}{16}$-inch to $\frac{5}{32}$-inch in diameter.

SURFACE GAGE

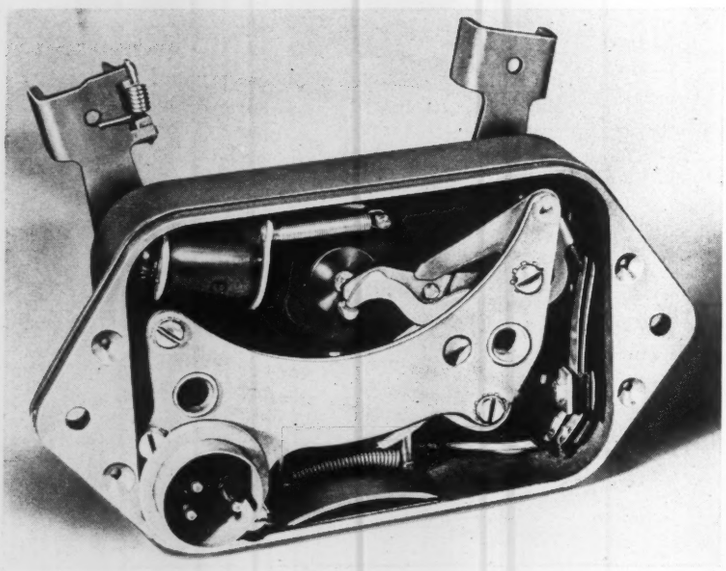
Work table of this surface gage developed by Yankee Precision Products Co. is composed of closely spaced rest buttons arranged to duplicate the form and area of a piece to be gaged. Buttons are accurately ground and lapped to form a perfectly flat resting surface and each button is connected electrically to a small light in matching position on the upright face of the machine. When high or low spots appear, bulbs at those points on the pattern fail to light. Percentage of inaccuracy is indicated simultaneously by electric meters.

A special electronic circuit eliminates danger of sparking at the contacts. Positive "on" and "off" registration is obtainable with variations as small as 0.000005-inch. Principles involved can be adapted to a variety of requirements, including measurement of tapered bores, and irregular surfaces.

(New machines listed on Page 192)

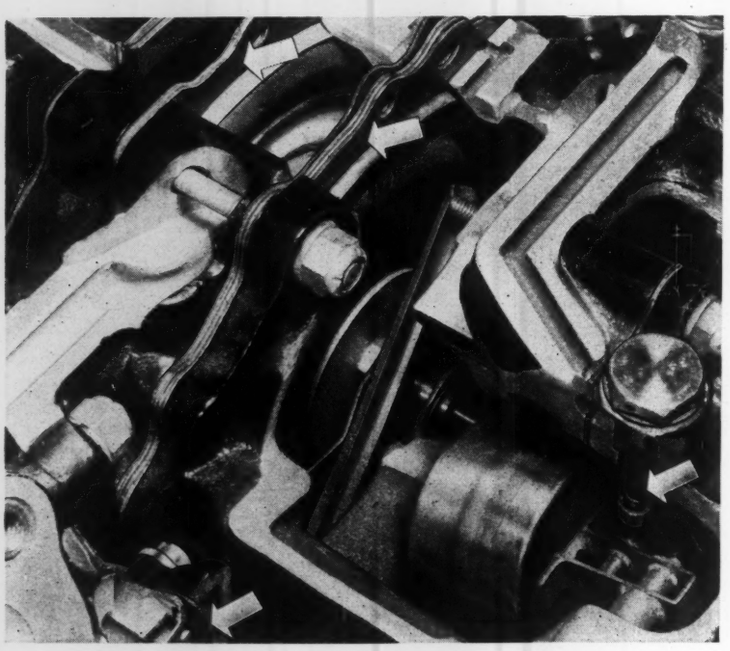
Applications

of Engineering Parts, Materials and Processes



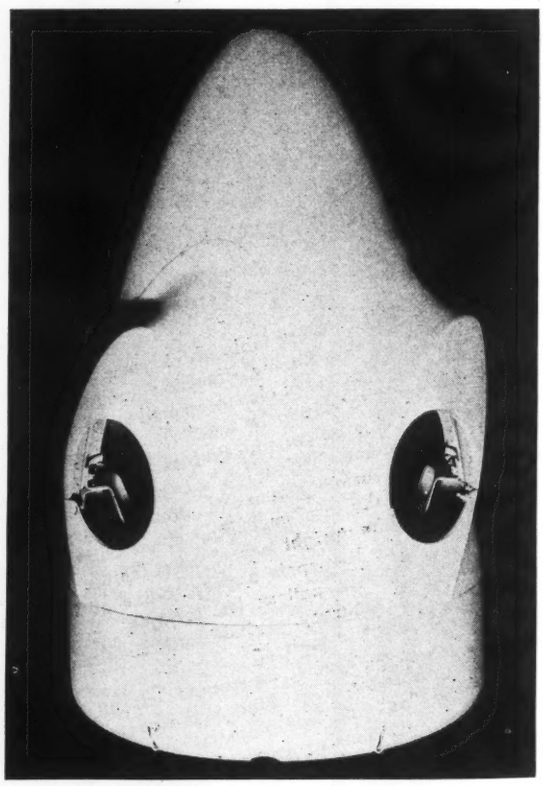
Diaphragms Eliminate Floats

UTILIZING Aero-Seal synthetic rubber diaphragms in lieu of a float mechanism, the Bendix aircraft carburetor, below, functions satisfactorily in any position or violent maneuver. Synthetic diaphragms also create a variable venturi replacing the conventional butterfly valve and fixed venturi. Continuous exposure to aviation gasoline has little or no effect upon the synthetic.



Uses Rotary Solenoid

COMPACTNESS, power, adaptability, and efficiency, in addition to immunity to accidental operation in case of severe shock, makes the Ledex rotary solenoid ideal for operating precision instruments such as the bomb release, left. In this mechanism, a lever rests upon a pin located ¼-inch from the axis of the solenoid where the force is greater than 16 pounds. On powering the solenoid release is effected instantly, the pin turning through approximately 45 degrees to allow the lever to drop.



Spinning Unusual Shapes

COMPLICATED sections of aircraft assemblies such as that shown above are spun from aluminum sheet by the Benson Manufacturing Co. Beyond the range of economical production by other methods, substantial quantities of these deep parabolic sections are most easily produced in the spinning lathe.

Nomogram Facilitates Helical Spring Design

By Carl P. Nachod
Nachod & United States Signal Co.

HELICAL spring calculations are greatly facilitated by use of the accompanying nomogram which appears on the next page. For a spring index of 8, which is a good average value, only two computing secants are needed to give the relations between load, deflection, stress, and wire diameter of steel springs. For other values of the spring index two more secants are needed.

The nomogram is based on the standard formulas for helical round-wire compression springs, which may be written as follows:

$$P=\frac{\pi d^3 S}{8KD}=\frac{\pi d^2 S}{8Kc}$$

$$f=\frac{\pi S D^2}{Gd}=\frac{\pi S c^2 d}{G}$$

$$c=\frac{D}{d}$$

$$K=\frac{4c-1}{4c-4}+\frac{0.615}{c}$$

where P is the load, pounds; f is the deflection per turn, inches; d is the wire diameter and D is the mean coil diameter, inches; S is the maximum stress in the wire, pounds per square inch; c is the spring index; and G is the torsional elastic modulus, which is assumed equal to 11.5 million psi for steel. Factor K is the Wahl correction for the increased fiber stress due to the coiling of the wire.

Basic portion of the chart, covered by Secants I and II, gives the relations for springs having spring index 8. Thus a wire of diameter $d = 0.2$-in., coiled to a mean diameter of $8d = 8 \times 0.2 = 1.6$ in., will support a load $P_8 = 100$ lb at 60,000 psi maximum stress, as shown by Secant I. The corresponding deflection per turn is $f_8 = 0.177$-in., as shown by Secant II.

For a spring index of 7, which gives a mean coil diameter $7d = 7 \times 0.2 = 1.4$ in., the load would be $P_c = 111$ lb, as indicated by Secant III, and the corresponding deflection per turn $f_c = 0.133$-in., shown by Secant IV.

Engineering Data Sheet

MACHINE DESIGN'S

MATERIALS WORK SHEET

FILING NUMBER
7.05

Heat and Corrosion Resistant Cast Steels

ASTM SPEC. NOS.: A198-39, A221-39, A222-39, A223-39.

Heat and corrosion-resistant alloy steels are of three primary types: Chromium, chromium-nickel and nickel-chromium. While the steels covered in this Work Sheet are representative of the heat and corrosion-resistant alloys in most general use, many modifications of them also are available to meet specific requirements.

PROPERTIES PRESCRIBED IN ASTM SPECIFICATIONS

Class	Chemical Composition C	Mn	P	S	Si	Ni	Cr	Mo	W	Cu	Tensile Strength (min, psi)	Yield Point (min, psi)	Elong. in 2 in. (min, %)	Red. of Area (min, %)
Spec. No. A198-39—20 per cent Chromium, 9 per cent Nickel Alloy-Steel Castings														
A[a]	0.07 max	1.00 max	0.05 max	0.05 max	2.00 max	8.00 min	18.00 min	....	....	.....	70,000	30,000	35	40
B[a]	0.20 max	1.00 max	0.05 max	0.05 max	2.00 max	8.00 min	18.00 min	....	....	.....	70,000	30,000	35	40
Spec. No. A221-39—Chromium Alloy-Steel Castings														
A	0.15 max[b]	0.25-0.75	0.05 max	0.05 max	1.00 max	0.80 max	11.5-14.0[b]	....	....	.....	80,000	50,000	20	30
B	0.30 max	0.25-0.75	0.05 max	0.05 max	1.00 max	1.00 max	17.0-21.0	....	....	0.9-1.2[c]	90,000	55,000	5	5
C	0.25-0.50	0.25-0.75	0.05 max	0.05 max	0.80 max	3.00 max	26.0-30.0	....	....	.....	55,000	40,000	..	..
Spec. No. A222-39—Chromium-Nickel Alloy-Steel Castings														
A	0.25 max[d]	0.25-1.00	0.05 max	0.05 max	0.25-1.50	11.0-13.0	22.0-26.0	....	....	.....	70,000	0.45 ts	30	30
B	0.30 max	0.25-1.00	0.05 max	0.05 max	0.25-1.50	19.0-22.0	23.0-27.0	....	....	.....	72,500	0.45 ts	25	25
C	0.30 max	0.25-1.00	0.05 max	0.05 max	0.25-1.50	8.00-10.0[e]	26.0-30.0	....	....	.....	85,000	0.45 ts	20	20
Spec. No. A223-39—Nickel-Chromium Alloy-Steel Castings														
A	0.20 max[f]	0.25-1.00	0.05 max	0.05 max	0.25-2.00	19.0-22.0	8.00-10.0	....	....	.....	65,000	30,000	30	35
B	0.60 max	0.25-1.00	0.05 max	0.05 max	0.50-1.75	34.0-37.0	14.0-17.0	....	....	.....	60,000	0.45 ts	..	..

[a] Molybdenum (2.00 to 4.00 per cent) is sometimes employed for particular and more severe general corrosive conditions and may be specified by agreement between manufacturer and purchaser.
[b] If carbon content of class A castings exceeds 0.12 per cent, the chromium content shall not be less than 12.50 per cent.
[c] Copper is required for heat-resisting castings of class B.
[d] Castings intended for high-temperature service may have a maximum carbon content of 0.40 per cent.
[e] For certain applications a nickel content within the range of 10 to 12 per cent is desirable for class C castings.
[f] Class A castings intended for high-temperature service may have a maximum carbon content of 0.35 per cent.

CHARACTERISTICS

Heat-resistant castings may be classified as chromium, chromium-nickel or straight chromium steels intended for service at a metal temperature of 900 F or higher. Corrosion-resistant steels, popularly referred to as "stainless steels", are considered as any nickel-chromium, chromium-nickel, or straight chromium steel that is intended for use in contact with corrosive agents at temperatures less than 900 F or up to 1200 F under conditions of high pressure and corrosion. Heat and corrosion-resistant alloys should not be confused with the so-called alloyed cast irons carrying high percentages of nickel or chromium.

As a group, heat-resistant irons and steels are higher in alloy content than corrosion-resistant alloys. High chromium content is distinctive in improving corrosion, abrasion and oxidation resistance. The addition of nickel improves high-temperature strength, shock resistance and corrosion resistance.

12 to 14% Chromium Cast Steels: These are produced in fairly large quantities. In addition to the grade covered by ASTM Spec. No. A221-39, Class A, there is another in which carbon content ranges from 0.15 to 0.35 per cent. Susceptibility to heat treatment increases with increases in carbon content. Sulphur (0.25 to 0.40%) or selenium (0.10 to 0.25%) impart free machining properties.

16 to 20% Chromium Cast Steels: These grades are covered by ASTM Spec. No. A221-39, Class B. They are less ductile than those of the 12 to 14 per cent grade, but this is no drawback in many cases where resistance to corrosion is the major consideration. Their machinability is about the same as that

MACHINE DESIGN is pleased to acknowledge the collaboration of the Steel Founders' Society of America in this presentation. Much of the data included is based on the Society's *Steel Castings Handbook*.

of medium carbon steel or of low-alloy cast steel of about the same brinell hardness. The corrosion resistance of the 16 to 20 per cent chromium cast steels with 0.20 to 0.30 per cent carbon is greater than that of steels containg 10 to 14 per cent chromium, 0.12 per cent carbon.

25 to 30% Chromium Cast Steels: Applying specification is ASTM No. A221-39, Class C. With carbon content ranging from 0.25 to 0.50 per cent, these steels are widely used for resistance to oxidation at elevated temperatures. Mechanical properties are not high, but few of the applications to which they are put require great strength.

18 to 22% Chromium, 7 to 9% Nickel Cast Steels: These are the familar 18-8 stainless steels. Due to their superior general resistance to corrosion they have supplanted some of the straight chromium alloys, particularly those castings with 20 per cent chromium or less. They have the desirable combination of fair tensile strength, excellent ductility and good corrosion resistance. They may be divided into two grades, depending upon their carbon content. One grade (ASTM A198-39, Grade A) has a maximum carbon content of 0.07 per cent. The other grade (ASTM A198-39, Grade B) contains a maximum of 0.20 per cent carbon. The low-carbon alloy often is made into castings without introducing any other carbide forming element into the analysis and is used where welding is to be employed in assembly. For castings not subject to the severest corrosion and which cannot be liquid quenched because of design, size or section, a maximum carbon content of 0.07 per cent is employed. The higher carbon grade has a marked corrosion resistance to a host of corroding agents at temperatures under about 800 F. These steels, when given the proper heat treatment, have relatively high resistance to single-blow impact. Several modified types of 18-8 are employed in castings for specific purposes.

22 to 26% Cr, 10 to 13% Ni Cast Steels (24-12 Type): These offer the desirable combination of fair tensile strength, excellent ductility and good corrosion resistance. They are covered by ASTM Spec. No. A222-39, Class A, and occupy an important position in the heat and corrosion-resistant field. With these aloys, as in the case of the 18-8 grade, it may be preferable to introduce stabilizing elements (Cb, Ti and Mo) to prevent harmful carbide precipitation.

23 to 27% Cr, 19 to 21% Ni Cast Steels (25-20 Type): These may be purchased under ASTM Spec. No. A222-39, Class B. They are used for both heat and corrosion-resistant applications.

12 to 14% CHROMIUM CAST STEELS

(normally expected values)

Composition (%)					Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Brinell Hard. No.
C	Cr	Mn	Si	Other						
0.08	11.94	0.41	0.38	.....	1800 AC, 1250 T	93,100	73,800	26.0	65.8	179
0.08	12.08	0.39	0.52	.....	1850 AC, 1200 T	91,200	72,000	25.5	55.0	184
0.10	11.50	0.34	0.56	.....	1850 WQ, 1000 T	114,000	57,000	18.8	44.8	236
0.10	11.98	0.70	0.90	.....	1950 AC, 1300 T	104,600	80,900	23.0	50.6	...
0.11	12.15	0.60	0.70	.....	1850 WQ, 1200 T	99,500	64,000	20.0	43.0	190
0.12	12.00	0.58	0.97	.....	1875 AC, 1200 T	89,000	63,000	25.5	51.0	...
0.12	12.40	0.47	0.54	.....	1850 AC, 1600 AC, 1350 FC	95,300	76,200	26.5	60.3	197
0.10	13.50	0.42	0.74	Se 0.20	1650 FC	80,900	57,800	25.0	47.4	187
0.10	13.50	0.42	0.74	Se 0.20	1850 AC, 1300 T	102,500	80,400	20.5	52.1	212
0.10	13.50	0.42	0.74	Se 0.20	1850 OQ, 1300 T	101,100	82,500	21.5	50.6	...
0.07	14.40	0.37	0.69	Se 0.20	1850 AC, 1250 T	102,300	83,200	16.0	41.1	...
0.15	11.32	0.51	0.56	Ni 1.00	1850 AC, 1600 AC, 1250 T	104,300	80,000	25.0	60.3	217
0.16	11.18	0.48	0.55	Ni 0.90	1850 AC, 1600 AC, 1300 T	116,350	98,200	24.2	56.0	222
0.17	12.73	0.15	1.29	.....	1800 AC, 1200 T	114,850	57,100	17.5	30.4	...
0.18	13.00	0.45	0.85	.....	1775 AC, 1400 AC	101,000	73,000	24.1	52.1	225
0.19	13.50	0.46	0.75	Mo 0.35	1750 AC, 1400 FC	95,000	60,000	27.0	55.0	200
0.25	13.87	0.43	0.78	.....	1800 AC, 1200 T	117,000	73,000	18.0	35.0	234
0.30	12.09	0.59	0.73	V 0.25†	1600 AC, 1400 AC	120,000	79,000	17.5	29.2	250

*AC = Air cooled; FC = Furnace cooled; T = Tempered; WQ = Water quenched; OQ = Oil quenched.
†Plus Mo 0.47 per cent.

18-22% CR, 7-9% NI CAST STEELS

(normally expected values)

Composition (%)								Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)
C	Cr	Ni	Mn	Si	Cb	Ti	Ag					
0.05	18.65	8.64	0.65	0.44	0.44	...	...	2050 WQ	82,300	40,500	52.0	61.1
0.06	18.56	8.65	0.54	2.79	...	...	...	2050 WQ	78,600	43,500	58.5	69.9
0.06	19.91	10.38	0.33	3.14	...	0.35	...	2050 WQ	93,500	50,000	43.3	48.1
0.06	20.22	9.23	0.59	1.25	...	...	...	2050 WQ	76,160	38,320	55.1	65.2
0.06	19.44	9.12	0.50	0.52	...	...	...	1950 AC	83,500	42,000	53.3	58.5
0.07	19.47	9.51	0.76	1.22	...	...	0.26	2050 WQ	76,675	36,875	59.3	68.2
0.07	18.75	9.00	0.95	2.25	...	...	...	1900 WQ	88,000	45,000	60.0	55.0
0.07	18.75	9.00	0.85	0.90	0.85	...	...	1900 WQ	92,000	53,000	45.0	55.0
0.08	19.94	8.72	0.63	1.88	...	...	...	1900 AC	85,850	41,440	51.0	61.4
0.08	19.67	10.06	0.64	1.20	0.61	...	...	2050 WQ	72,250	34,000	54.0	56.6
0.09	19.92	8.69	0.50	1.10	0.94	...	...	1950 AC	89,220	44,600	49.0	54.3
0.11	19.04	9.06	0.48	0.67	...	...	...	2100 WQ	85,000	48,000	52.0	60.0
0.12	19.10	9.64	0.53	0.55	...	...	...	2000 WQ	71,900	43,000	55.0	64.7
0.13	19.17	9.22	0.82	0.95	...	...	...	2000 WQ	73,850	35,350	52.5	64.2
0.14	19.10	8.30	0.62	0.53	...	...	...	2000 WQ	78,200	44,700	61.0	66.0
0.15	20.05	10.12	0.40	1.20	...	...	...	2100 WQ	86,640	42,000	47.0	52.0

*WQ=Water quenched; AC=Air cooled.

ELEVATED-TEMPERATURE PROPERTIES OF 18-22% CR, 7-9% NI CAST STEELS

(test values with separately cast specimens)

Composition (%) C	Mn	Si	Cr	Ni	Water Quench from (F)	Testing Temp. (F)	Tensile Strength (psi)	Yield Point (psi)	Prop. Limit (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Creep* Stress (psi)
						70	71,400	30,800	18,300	55.0	62.5	.....
						800	58,000	18,000	5,000	47.0	56.2	.....
0.10	0.48	0.28	18.72	10.00	1900	1000	51,800	14,500	.....	39.0	47.8	.....
						1200	41,000	14,000	.....	29.5	41.8	.....
						1400	24,900	.....	.....	13.5	23.4	.....
						1600	16,000	.....	.....	16.0	38.8	.....
						70	64,500	28,000	36,000**	66.0	...	.....
0.07	0.50	0.65	18.21	9.56	2000	1000	44,600	.....	.....	44.0	59.5	14,500
						1200	37,000	.....	20,000**	39.0	55.0	8,500
						70	64,500	31,200	35,000**	59.0	...	.....
						900	54,600	.....	.....	50.0	57.5	.....
0.125	0.47	0.58	18.50	9.67	2000	1000	49,300	.....	.....	...	...	22,500
						1100	.....	.....	.....	38.0	40.2	17,000
						1200	40,400	.....	23,000**	37.0	50.5	9,000

*For an elongation of 1 per cent in 10,000 hours.
**Endurance limit.

18-22% CR, 7-9% NI, 2.5-4% MO CAST STEELS

(normally expected values)

Composition (%) C	Cr	Ni	Mn	Si	Mo	Other	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)
0.04	19.03	9.43	0.75	1.03	3.18	....	2050 WQ	80,000	43,400	50.0	70.2
0.05	18.89	8.26	0.61	0.73	3.76	....	2050 WQ	89,600	56,600	49.0	64.3
0.06	20.71	9.76	0.67	1.24	2.93	....	2050 WQ	88,850	52,360	43.7	68.1
0.06	20.12	9.47	0.71	1.21	3.02	Ag 0.28	2050 WQ	87,450	51,750	45.2	69.1
0.06	20.51	9.67	0.60	1.22	2.96	....	2000 WQ	82,900	47,400	47.0	65.8
0.06	19.66	9.66	0.65	1.02	286	....	2000 WQ	84,750	46,000	48.0	62.6
0.06	20.03	9.98	0.48	0.84	3.26	....	2000 WQ	89,000	47,500	40.0	67.1
0.07	19.30	9.20	0.57	0.96	2.38	Se 0.20	2000 WQ	80,200	48,100	54.0	68.4
0.07	20.00	8.56	...	...	3.00	Se 0.20	2000 WQ	85,100	47,500	40.0	64.9
0.07	18.75	9.00	0.85	0.90	2.85	....	1900 WQ	85,000	48,000	53.0	55.0
0.07	19.83	9.67	0.54	1.13	317	....	2050 WQ	81,750	44,000	43.0	72.1
0.07	20.61	10.21	0.64	1.14	2.76	....	2050 WQ	87,900	48,500	41.5	69.5
0.07	18.40	9.27	0.62	0.64	3.50	....	2050 AC	89,500	52,000	42.0	44.9
0.10	18.09	8.38	0.49	1.69	3.08	....	1950 AC	89,200	45,000	49.0	...
0.12	19.02	9.07	0.68	0.88	4.05	....	2200 WQ	97,000	67,000	38.0	49.0

* WQ = Water quenched; AC = Air cooled.

26 to 30% Cr, 7 to 10% Ni Cast Steels (29-9 Type): An important type in the corrosion-resistant field, it is covered by ASTM Spec. No. A222-39, Class C. One of its valuable characteristics in the carbon range of 0.20 to 0.30 per cent is its resistance to intergranular attack in the "as cast" condition, being comparable to that developed by fully heat treating the very low carbon 18-8 castings. By cooling 29-9 alloy rapidly from 2000 F, its resistance to corrosion is still further improved. In commercial practice it has been found satisfactory to use this material in the "as cast" condition. This characteristic has made 29-9 particularly useful in cases where castings, because of their size or design, cannot be heat treated conveniently. Cast 29-9 has satisfactory tensile properties; a somewhat higher yield point and tensile strength with lower ductility than 18-8. It is used for heat-resistant as well as corrosion-resistant applications. For high-temperature service it is produced with higher carbon content (0.30 to 0.60%) and in some cases slightly higher nickel content (8 to 12%). Although its ductility at room temperature is lower than that of the corrosion-resistant type due to its higher carbon content, it has sufficient toughness at room temperature for most construction purposes. Its useful strength at high temperatures is slightly better than that of 18-8.

17 to 22% Ni, 6 to 10% Cr Cast Steels: These, among the oldest of corrosion-resistant alloys, are covered by ASTM Spec. No. A223-39, Class A. They have high strength at elevated temperatures and, where such service is intended, carbon content usually is held within the range of 0.20 to 0.50 per cent.

34 to 37% Ni, 13 to 17% Cr Cast Steels: Covered by ASTM Spec. No. A223-39, Class B, these are used extensively where strength at elevated temperatures is an important factor. Recommended design values (working stresses) for various temperatures are:

Temperature (F)	Working Stress (psi)
1250	5800
1300	5000
1400	3600
1500	2500
1600	1500
1800	500

Under high-temperature conditions, these alloys exhibit a combination of strength and freedom from scaling.

68% Ni, 19% Cr and 65% Ni, 15% Cr Cast Steels: Alloys that use nickel rather than iron as a base are inherently heat-resistant alloys. Chromium, iron and carbon added to nickel impart stiffness, strength and hardness. High nickel-chromium alloys extending from 68% Ni, 19% Cr down to 35% Ni, 15% Cr comprise the great bulk of structures exposed to heat in metallurgical furnaces. The 65% Ni, 15% Cr alloy has considerable resistance to deformation and oxidation when subjected to the frequent intermittent temperatures encountered in such furnaces.

APPLICATIONS

12 to 14% Chromium Cast Steels: Used in valve bodies, valve disks and seats, gears and similar parts where a tough metal is needed to resist mild corrosion.

16 to 20% Chromium Cast Steels: The medium-carbon type is employed for valve bodies and trim for steam and oil service at elevated temperatures. Equipment for production of nitrogen, nitric acid, acetate rayon and the food processing industries is also made from this alloy cast steel. With the addition of copper it is used for moderate heat resistance, as in exhaust manifolds and tube supports.

25 to 30% Chromium Cast Steels: Recommended for corrosion-resistant service in equipment operating in or carrying alkaline liquors, fumes of volatile heavy metals, oxidizing acids, mine water and sulphur-rich atmospheres at high temperatures. Typical applications are annealing boxes, lead pots, roasting furnace rabble arms, and pump and valve bodies.

18 to 22% Chromium, 7 to 9% Nickel Cast Steels (18-8): Typical applications consist of pump casings, impellers, valves, valve trim, fittings, conveyor chain and links, etc. Also used for salt water service where the water is in constant motion such as in pumps, etc., and throughout chemical processing industries. Streamlined trains and airplanes, as well as speed boats and automobiles are using more and more cast 18-8, as its ornamental value and resistance to atmospheric corrosion make it a desirable material for modern design.

22 to 26% Cr, 10 to 13% Ni Cast Steels (24-12): Castings of this type find satisfactory application under conditions where the atmosphere is strongly sulphidizing and especially where it is at the same time reducing, such as in chemical roasting equipment and in furnaces in which the atmosphere requires a material resistant to sulphur attack. These castings give excellent corrosion-resistance at normal temperatures, being used in the paper and pulp processing and chemical industries.

26 to 30% Cr, 7 to 10% Ni Cast Steels (29-9 Type): Resist the same general types of corrosion in the "as cast" condition for which the heat-treated 18-8 alloys are suitable. The sulphite and paper industries use a considerable tonnage of this material in the form of valves, fittings, pump parts and pipe connections which are required to resist the corrosive action of calcium bi-sulphite liquor. These castings are also useful in marine service for resisting salt water corrosion; in the rayon industries; for various parts required to resist the action of hot sulphur dioxide; for resistance to nitric, phosphoric, and some of the organic acids such as citric and lactic acids. This alloy should not be used in the presence of more than very small amounts of hydrochloric and sulphuric acids. The heat-resisting types have found particular utility in the construction of industrial furnaces in which reducing atmospheres in the presence of products of combustion high in sulphur are maintained. In this service the material is used in the form of conveyor chains, beams, rails, trays, shafts, rollers, etc. Also well adapted to resist oxidation at high (1200 to 1800 F) temperatures.

17 to 22% Ni, 6 to 10% Cr Cast Steels: Typical applications are: Pump and valve bodies, impellers, rayon-producing equipment and box plugs for oil still headers. These steels are used for resisting the corrosion of sulphuric acid in a wide range of concentration and temperature, mine waters, steam, high-sulphur oils and alkaline liquors.

34 to 37% Ni, 13 to 17% Cr Cast Steels: Their combination of strength plus freedom from scaling at high temperatures makes these steels suitable for furnace conveyor rolls, glass rolls, enameling racks, tube supports, radiant heater tubes, carburizing tubes and retorts.

65% Ni, 15% Cr Cast Steels: Castings of these steels find use as furnace parts, carburizing boxes, pots, pot covers, retorts, conveyors, trays, muffles and other fixtures, structures and members which are exposed to high heat and prolonged applications of heat.

26-30% CR, 7-10% NI CAST STEELS

(normally expected values)

Composition (%) C	Cr	Ni	Mn	Si	Heat Treament* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)
0.17	27.56	9.51	0.57	1.00	As cast	97,125	46,500	29.0	32.8
0.22	28.54	9.92	0.27	0.91	As cast	96,050	47,750	27.0	29.5
0.26	28.60	8.50	0.59	1.00	As cast	97,850	59,000	31.5	30.8
0.28	29.72	8.54	0.51	0.84	As cast	105,350	62,000	23.0	21.3
0.33	30.34	11.00	0.77	1.10	As cast	97,650	49,000	28.0	28.5
0.16	28.22	9.20	0.62	0.93	2050 WQ	92,000	46,000	34.0	34.8
0.20	28.05	10.71	0.40	0.96	2000 AC	95,680	49,400	30.0	29.8
0.24	28.55	9.59	0.84	1.35	2050 WQ	97,250	61,750	20.6	21.6

*WQ = Water quench; AC = Air cooled.

34-37% NI, 13-17% CR CAST STEELS

(normally expected values)

Composition (%) C	Ni	Cr	Mn	Si	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Brinell Hard. No.
0.38	36.16	18.02	...	...	As cast	64,000	41,200	7.0	7.8	165
0.42	35.12	15.05	0.68	1.35	As cast	60,000	44,500	3.5	2.0	168
0.40	37.88	17.03	0.96	1.02	As cast	64,000	49,500	1.5	1.7	...
0.40	36.08	17.96	0.83	1.14	As cast	75,000	41,000	7.0	7.0	165
0.46	36.10	15.80	1.37	1.04	As cast	69,000	40,500	7.5	6.8	...
0.46	36.10	15.80	1.37	1.04	1400 AC	84,650	48,000	4.7	4.0	...
0.49	36.24	16.56	0.74	1.18	As cast	63,000	41,500	5.0	8.0	185
0.50	36.00	16.00	0.70	1.50	As cast	66,000	.....	6.0	3.0	185
0.50	35.44	15.21	0.78	1.31	As cast	61,500	42,000	3.5	2.5	176
0.50	35.84	15.00	0.81	1.26	As cast	74,250	41,000	7.8	7.3	...
0.14	35.15	15.85	1.27	2.21	2100 AC	69,420	35,440	27.5	40.5	143

*AC=Air cooled.

22-26% CR, 10-13% NI CAST STEELS

(normally expected values)

Composition (%) C	Cr	Ni	Mn	SI	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Brinell Hard. No.
0.10	25.03	11.53	0.78	0.81	As cast	80,500	40,500	43	56.0	170
0.10	25.03	11.53	0.78	0.81	2000 AC	85,000	46,500	49	65.0	156
0.12	25.11	11.02	0.63	0.96	1950 AC	80,100	53,400	42	41.5	146
0.15	26.04	12.51	0.45	1.15	2200 WQ	92,000	62,000	45	50.0	...
0.18	22.53	11.39	0.59	1.24	2050 WQ	81,800	48,000	51	56.0	...
0.25	25.50	11.04	0.68	0.98	2100 WQ	96,000	60,000	30	35.0	...
0.35	25.97	12.48	0.65	0.85	As cast	89,000	41,000	33	27.0	179
0.35	25.97	12.48	0.65	0.85	2100 AC	88,000	44,000	39	48.0	174

*WQ = Water quench; AC = Air cooled.

65% NI, 15% CR CAST STEELS, AS CAST

(normally expected values)

Composition % C	Ni	Cr	Mn	Si	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Brinell Hard. No.
0.31	64.96	16.22	1.23	1.35	67,650	40,000	10.0	22.3	167
0.40	65.12	19.78	1.47	1.52	61,500	45,250	6.8	7.0	...
0.44	63.90	16.60	1.15	1.08	70,100	39,900	9.7	9.7	176
0.45	65.33	15.51	1.02	1.42	63,000	48,500	4.0	3.0	170
0.50	61.10	19.48	1.75	1.00	60,000	46,000	1.2	2.9	...
0.60	62.74	14.55	1.03	1.54	67,500	41,500	3.0	3.2	...
0.68	67.41	18.12	1.11	1.65	60,500	40,250	3.0	5.0	185
0.80	65.96	18.88	1.94	1.50	66,000	49,000	2.0	2.4	188

FABRICATION

MACHINABILITY:

The following rate figures (based on machinability of wrought stainless steels) express approximate machinability in percentages of the speed at which bessemer screw stock is machined.

Type of Cast Steel—ASTM Spec. No.	Types	Rating (%)
A198-39, Classes A and B	18-8	40 to 45
A221-39, Class A	10-14% Cr	50 to 55
A221-39, Class A, (with sulphur added)	10-14% Cr (with sulphur added)	80 to 85
A221-39, Class A, (with high carbon content)	10-14% Cr (with high carbon content)	40 to 45
A221-39, Class C	25-30% Cr	40 to 45
A222-39, Class A	24-12	40 to 45

WELDABILITY:

Chromium Alloys: These constitute stainless irons having 12 to 28 per cent chromium as the primary alloy ingredient. They show a tendency toward grain growth in and near the weld which increases markedly with chromium content and, in high-chromium alloys, sometimes results in brittleness of the welded members. Small additions of nitrogen alleviate this tendency toward grain growth. The 15 to 18 per cent chromium irons with 0.10 per cent maximum carbon content are widely used where welding is required. Chromium irons may be welded by the oxyacetylene method provided adequate precautions are taken, best results being obtained with a practically neutral flame. Electric-arc methods, mainly the metallic arc, are also successfully used.

Chromium-Nickel Alloys: The accumulation of carbides at the grain boundaries in the narrow zones adjacent to welds generally will show less resistance to many corrosive media than metal some distance from the weld. For this reason, wherever practicable, the welded member is heat treated after welding except where columbium or titanium is present as a stabilizing element. Gas welding may be used on castings of light section, best results being obtained with a practically neutral flame. Direct-current arc welding is satisfactorily employed using reversed polarity, that is, work negative and electrode positive. Since these steels are susceptible to grain growth at high temperature, the welder is well advised to avoid overheating.

CORROSION RESISTANCE

In liquid solutions the corrosion rate depends upon a number of factors acting together or independently such as: Acidity or alkalinity, oxidizing capacity (oxygen content), temperature, velocity and electrolytic effects (galvanic and concentration cell). Corrosion resistance is not a constant property of an alloy, but varies with the environment in which the alloy may be used. Further, corrosive attack on various alloys depends largely on the nature and temperature of the atmosphere. In selecting or ordering high-alloy cast steels for a particular purpose it is advisable to state the analysis of the atmosphere, the maximum service temperature and the load to be carried. Data on general corrosion resistance for the various alloys are given under the heading "Applications" in this Work Sheet. For more specific information on corrosion resistance, refer to the table "Corrosion Resistance of High-Alloy Cast Steels for Industrial Service in Acids," on Page 156.

HEAT TREATMENTS

The 12 to 14% chromium cast steels (ASTM Spec. No. A221-39, Class A) may be liquid quenched where design permits. ASTM specifications call for normalizing at not less than 1875 F followed by drawing at not less than 1100 F nor greater than 1350 F and then cooling in air.

Specifications of ASTM for 16 to 20% chromium cast steels

call for heat treatment to relieve stresses. An anneal between 1450 and 1550 F is recommended, followed by furnace cooling to 1100 F and removal into air for final cooling.

For 25 to 30% chromium cast steels, ASTM recommends that all castings for corrosion-resisting service receive a stress-relieving treatment. They are to be annealed betwen 1450 and 1550 F, slowly furnace cooled to 1100 F and then cooled in air. Heavy sections requiring maximum impact toughness may be watercooled from 1100 F. Small castings of simple design may be water quenched from 1650 F with no further treatment to obtain best machinability.

The 18-8 cast steels (ASTM Spec. No. A198-39) are heat treated at 1900 to 2100 F for a sufficient time to insure the solution of the carbides followed by cooling at a rate to insure their retention in solution. Liquid quenching or air cooling is used, depending on the size, shape and design of any given casting.

Castings of the 24-12 type intended for corrosion-resistant service are usually heat treated by thoroughly heating to temperatures between 1900 and 2200 F, followed by quenching in water or air, depending on the mass, shape or design of the castings. In some cases intricate castings may require tempering. The tempering temperature usually does not exceed 800 F. If castings of the 24-12 type are intended for high-temperature service (800 F or above), heat treatment usually is not specified.

Castings of the 17 to 22% Ni, 6 to 10% Cr steels, intended for corrosion-resistant service are heat treated by quenching in water or air cooling from a temperature of 1900 F or higher. Method of cooling depends on the design of the castings. Castings intended for high-temperature service usually are not heat treated.

Heat treatment of the 35% Ni, 15% Cr cast steels, covered by ASTM Spec. No. A223-39, Class B, usually is not required.

CORROSION RESISTANCE OF HIGH-ALLOY CAST STEELS FOR INDUSTRIAL SERVICE IN ACIDS

(*all steels heat treated.*)

Composition (%)							Corrosion Medium Temperature and Concentration	Exposure Time (hrs)	Rate mg/cm²/hr	Rate Inches per mo.	Remarks
C	Mn	Si	Cr	Ni	Mo	Cu					
18-8 Type											
0.06	0.74	1.02	19.79	9.21	....	....	Boiling 67% HNO_3	144	.0148	.00056	....
0.11	0.77	1.13	19.35	8.41	....	....	Boiling 67% HNO_3	144	.0196	.00070	....
0.07	0.25	1.17	19.11	9.04	....	....	Boiling 67% HNO_3	144	.0190	.00070	....
0.05	0.57	0.73	20.40	8.88	....	....	Boiling 67% HNO_3	144	.0132	.00050	....
0.08	0.59	0.99	20.28	8.80	....	....	Boiling 67% HNO_3	144	.0125	.00050	....
0.14	0.74	1.03	18.60	9.43	....	....	Boiling 67% HNO_3	144	.0194	.00070	....
0.14	0.68	0.96	22.11	9.40	....	....	Boiling 67% HNO_3	144	.0170	.00060	....
0.07	0.81	1.17	19.49	8.88	....	....	Boiling 67% HNO_3	144	.0080	.00030	....
0.05	0.57	0.73	20.40	8.88	....	....	70 F, 1-1 HCl	24	1.4300	.05400	Not satisfactory
18-8 Mo Type											
0.07	0.71	1.15	18.25	9.83	2.93	....	Boiling 67% HNO_3	144	.0257	.00097	18-8 preferred for HNO_3
0.06	0.68	1.05	20.40	12.57	3.27	....	Boiling 67% HNO_3	144	.0242	.00090	18-8 preferred for HNO_3
0.07	0.71	1.15	18.25	9.83	2.93	....	70 F, 1-1 HCl	24	1.7500	.06600	Not practical for HCl
18-8 Ag Type											
0.07	0.76	1.22	19.47	9.51		(Ag 0.27)	Boiling 67% HNO_3	144	.0126	.00047	Similar to 18-8
28-12 Type											
0.26	0.63	1.18	28.18	12.10	....	....	70 F, 1-1 HCl	24	2.0400	.07700	Not good for HCl
0.26	0.63	1.18	28.18	12.10	....	....	Boiling 67% HNO_3	144	.0765	.00290	18-8 preferred
0.26	0.63	1.18	28.18	12.10	....	....	Boiling 5% H_2SO_4	1	9.1500	.34590	Not good for H_2SO_4
0.30	0.58	1.02	28.27	11.00	3.18	....	70 F, 1-1 HCl	24	10.6000	.40070	Not practical for HCl
0.30	0.58	1.02	28.27	11.00	3.18	....	Boiling 67% HNO_3	144	.0076	.00030	Excellent
0.30	0.58	1.02	28.27	11.00	3.18	....	Boiling 10% H_2SO_4	24	1.2700	.04800	Good
35-15 Type											
0.40	0.88	1.34	15.38	34.59	....	....	70 F, 1-1 HCl	24	.2800	.01060	Fair
0.40	0.88	1.34	15.38	34.59	....	....	Boiling 67% HNO_3	144	.1430	.00540	18-8 preferred
0.40	0.88	1.34	15.38	34.59	....	....	Boiling 5% H_2SO_4	5	1.1200	.04230	Not good for H_2SO_4
0.40	0.88	1.34	15.38	34.59	....	....	Boiling 10% H_2SO_4	5	2.1200	.08010	Not good for H_2SO_4
0.04	0.62	0.61	15.07	35.37	3.19	....	70 F, 1-1 HCl	24	.0245	.00090	Excellent
0.07	0.70	1.07	15.12	34.58	3.25	....	70 F, 1-1 HCl	24	.0260	.00090	Excellent
0.07	0.70	1.07	15.12	34.58	3.25	....	Boiling 67% HNO_3	144	.0490	.00190	18-8 preferred
0.07	0.70	1.07	15.12	34.58	3.25	....	Boiling 10% H_2SO_4	5	.6520	.02460	Not good for H_2SO_4
Misc. High Alloys											
0.06	0.64	0.90	15.73	35.98	....	2.18	70 F, 1-1 HCl	24	.0180	.00070	Excellent
0.06	0.64	0.90	15.73	35.98	....	2.18	Boiling 67% HNO_3	144	.0350	.00130	18-8 preferred
0.06	0.64	0.90	15.73	35.98	....	2.19	Boiling 10% H_2SO_4	504	.0090	.00030	Excellent
0.05	0.57	1.17	15.35	35.36	3.48	1.96	70 F, 1-1 HCl	24	.0175	.00700	Excellent
0.05	0.57	1.17	15.35	35.36	3.48	1.96	Boiling 67% HNO_3	144	.0570	.00220	18-8 preferred
0.05	0.57	1.17	15.35	35.36	3.48	1.96	Boiling 10% H_2SO_4	504	.0236	.00090	Good
0.05	0.79	0.94	20.11	29.87	3.29	4.79	70 F, 1-1 HCl	24	.0182	.00070	Excellent
0.05	0.79	0.94	20.11	29.87	3.29	4.79	Boiling 10% H_2SO_4	504	.0234	.00090	Good
0.05	0.50	0.63	19.84	29.85	2.82	5.03	Boiling 10% H_2SO_4	504	.0157	.00060	Excellent

Electrical Analogy

(*Concluded from Page* 132)

Under steady-state conditions, since the temperature is not varying with time, no heat is being stored in each element. Thus in the analogy no current is flowing into the capacitors and they have no influence on the solution. The circuit can then be formed entirely of resistors. Problems of this sort can be solved on a conventional power system d-c calculating board consisting of a d-c voltage supply and resistors.

HEAT CONDUCTION THROUGH A GAS TURBINE DISK: The example of *Fig.* 15 illustrates the use of an analogous circuit for heat flow media. The rotating gas turbine disk has circular symmetry in that equal temperatures exist at all points having the same value of the coordinates (r, z). Thus the differential elements can be circular rings and $r\Delta\theta$ for the equations of *Fig.* 14 become $2\pi r$. *Fig.* 16 shows the equivalent circuit representing the disk for the assumed elements given in *Fig.* 13. The problem is one of steady state and the capacitors are omitted. Known boundary conditions are the temperature at the periphery of the disk and at the left end of the disk, also the given distribution of temperature at the boundary of the cooling gas that flows out to the periphery. The resistors representing the surface heat transfer coefficients are shown in *Fig.* 16 together with the voltage circuit for establishing the boundary conditions.

Use of analogous circuits for distributed media of this sort opens a field of analysis of great importance. The only limitation to the accurate representation of the most complex shapes lies in the number of circuit elements that may be required. For heat flow problems especially these are quite inexpensive.

HYDRAULIC PROBLEMS: The electrical analogy can also be applied to problems in hydraulics. Consider, for example, the one-dimensional flow of liquid in a conduit. The physical laws defining flow and pressure in the differential length are given in *Fig.* 17 together with the analogous electrical circuit which, in this case, is basically the same for both the mass-inductance, force-voltage and the mass-capacitance, force-current analogies.

In the practical setup of the electrical analogy the capacitance and inductance cannot have infinite distribution, but must be arranged in finite blocks. The higher-frequency components of the solution are, as a consequence, in error and some may be entirely missing. Nevertheless, good first-order approximations may be secured with a reasonable number of system divisions.

Determining Flow and Pressure in Penstock

From the foregoing considerations it is evident that, if at time zero a given fluid velocity exists in the conduit and a certain flow variation function is initiated at the discharge end, an equivalent current (in the mass-inductance analogy) or a given voltage (in the mass-capacitance analogy) with the same time-variation rate must be established. These considerations are illustrated by the example in *Fig.* 18. This is a problem of determining the flow and pressure conditions in a penstock as a function of flow at the gate.

Since the equations of *Fig.* 17 were linear with constant coefficient, it is possible to superimpose any other pressure conditions such as those arising from head, etc. The advantage of using this method lies in the fact that the large amount of work necessary to secure a numerical solution is eliminated. This advantage grows rapidly with system complication such as that encountered in branched lines.

"This one has everything!"

PROFESSIONAL VIEWPOINTS

" . . . subcombination claims"

To the Editor:

I have read with interest the article, "How To Protect Machine Improvements" by George V. Woodling which appeared in the November issue of MACHINE DESIGN.

With respect to obtaining subcombination claims, I wish to direct your attention to the latest decision of the Supreme Court of the United States on the subject—Special Equipment Company vs Coe, Commissioner of Patents, No. 469, decided March 26, 1945.

—CHARLES S. PENFOLD, *Patent Dept.*
The Anderson Co.

To the Editor:

The decision referred to by C. S. Penfold covers a suit in equity brought to compel issuance of a patent upon a subcombination of the elements of a machine for which the inventor had previously filed a patent application covering the complete combination.

Specifications of the original application showed automatic mechanisms for performing successive operations of bobbing (cutting off stems), splitting, paring, and coring pears, in preparation for canning or other processing. In operation, as a pear is carried from one turret position on the machine to another, it is split by a fixed vertical knife. Following paring and coring, the mechanism separates the sections and discharges them.

Subcombination claims covered only the apparatus involved without the splitting knife mechanism, since presplit pears could be handled with the same result as whole ones. Rejected by the Patent Office as incomplete, too broad, misleading, and covering construction not contemplated, the rejection was sustained by the District Court with the further reason that the subcombination did not "combine to produce any useful result". This judgment of the District Court was upheld likewise by the Court of Appeals with the thought that the grant of a patent which the patentee had no intention of exploiting as a distinct invention was inconsistent and "for the purpose of blocking the development of machines which might be constructed by others".

Since the patentee merely expressed a purpose to prevent appropriation of the complete machine by appropriation of a part embodied in the subcombination, the Supreme Court in reviewing the case found nothing to suggest any purpose or reason for a purpose to enlarge the monopoly either of the subcombination or of the complete machine by tying together their uses. Control of a part could not, in the Court's opinion, be used as a means of enlarging an already acquired control of the whole. Obviously licensing the subcombination which is less useful than the whole combination would not be a practical means for enlarging the use of the whole.

Failure to acquire complete control of a whole machine was thought by the Supreme Court a legitimate reason—where purpose to enlarge the monopoly of either invention is absent—for wishing to acquire a subcombination patent as a means of preventing appropriation of the machine. Since the patent on the complete machine would not prevent free public use of the subcombination, the value of the former would be greatly impaired. Therefore the Court's final decision was that inasmuch as the subcombination was in itself a useful invention, it was entitled to claim the benefit and protection of the patent laws.

—GEORGE V. WOODLING

" . . . presents complete summary"

To the Editor:

I have read Macon Fry's articles "Designing Computing Mechanisms" with much interest as they apply directly to the work we are doing. The articles are valuable in that they present a complete summary of all ideas pertinent to the subject of computers. This intricate topic is being clearly and comprehensively presented by Mr. Fry.

The information contained in these articles is of such lasting value that I believe it would be well to compile them into a booklet form when the series has been finished.

—WILLIAM WEHLAU, *Project Engineer*
Victor Research Laboratory

" . . . a swell job"

To the Editor:

Thank you very much for sending me Parts I to IV of the series of articles on "Designing Computing Mechanisms" now appearing in MACHINE DESIGN. The author, Macon Fry, has done a swell job in bringing a highly complicated digest down to the level of most designers. He is to be congratulated. I believe that a reprint of the entire series, when completed, would be quite useful.

At this date, I believe there are at least six engineers here who would be interested in obtaining a reprint of this series for their reference files.

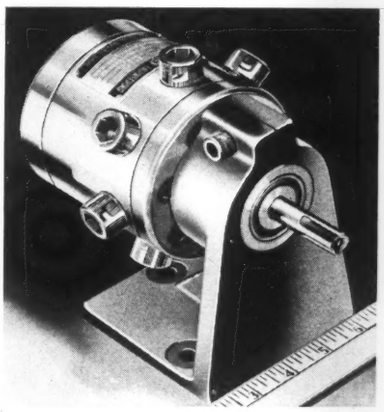
—A. H. GOTTESMAN, *Engineering Dept.*
Farrand Optical Co., Inc.

Reprints of this series of articles are being made available. Announcement of details appears on page 140 of this issue. ED.

NEW PARTS AND MATERIALS

Hollow-Piston Hydraulic Pump

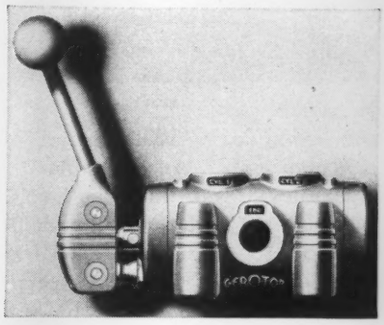
ANNOUNCED BY Simplex Engineering Co., Zanesville, O., radial hydraulic pumps utilize the principle of sealing by fluid pressure. Hollow pistons which generate the fluid compression function like cup leathers. As the fluid pressure builds up inside, it expands and sealing power is increased between the piston, cylinder wall and pump body. When pressure is released, surfaces return to their original dimensions. Deflections caused by the internal fluid pressures are within limits of the parts to



expand elastically and without permanent deformation. These pumps are not self-priming and should be installed below the oil reservoir. After priming they maintain a vacuum of 25 inches of mercury, providing the intake line is airtight. The pumps will maintain 3000 psi continuously and indefinitely, and 10,000 psi repeatedly. They are available with any style of bracket of foot mounting, and can be run in either direction at will.

4-Way Hydraulic Valve

RECENTLY ANNOUNCED by Gerotor May Corp., Logansport, Ind., a new 4-way hydraulic valve has a "floating piston" design which permits close fitting of the piston in the valve bore and gives maximum sealing ability. Valve stem is supported in its bearings in the valve covers without any influence on the piston fit in the valve body. Minimum leakage is gained not only from this close fit, but also from an O-ring seal design which prevents exhaust oil from leaking past piston stem. Suitable for oil service with pressures up to 1500 psi, the valves can be furnished for 2500 to 3000 psi oil service. For high-pressure water service, noncorrosive valves can be supplied. Four types of valve action are offered: Standard, spring return, spring



centered, and ball detent. The valves have five piston designs, and are obtainable with 6 methods of operation—hand, foot, cam, solenoid, oil pressure and air pressure. Seven sizes in which the valve is furnished include: ¼, ⅜, ½, ¾, 1, 1¼ and 1½ inches.

Motors and Gearmotors

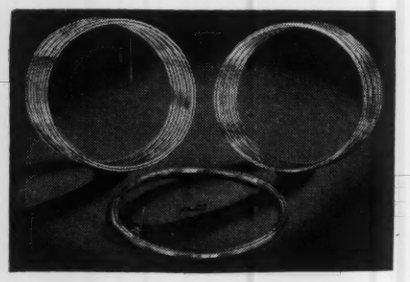
ADDITION OF two new types of motors have been added to the line produced by John Oster Mfg. Co., Racine, Wis. These are small precision capacitor synchronous and

induction motors for instrument and control applications where constant, unvarying performance is desired. Output range is 1/1000 to 1/2000 hp. The motors are

available in 4 pole or 2 pole types, with or without gear reduction. Weight of gearmotor unit is 33 ounces.

Extra-Thin Bearings

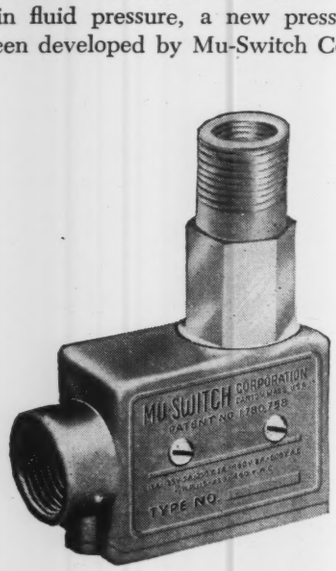
OF ANGULAR contact design, bearings 0.750-inch wide with an inside diameter of 30.500 inches and outside diameter of 32.000 inches, using ⅜-inch balls have been introduced by Kaydon Engineering Corp., Muskegon, Mich. Two bearings are mounted in opposite positions to take



the thrust and radial loads, each bearing taking thrust load in one direction only. An extra-thin bearing of the four-point contact design is 0.750-inch wide, 31.000 inches inside diameter, 33.000 inches outside diameter. Balls are 7/16-inch and 115 are used in each bearing. Taking the thrust in either direction, only one bearing is required instead of two of the angular contact type. While originally made for specific war needs, the precision bearing has many peacetime applications where minimum weight is essential, coupled with free movement and accuracy.

Pressure-Controlled Switch

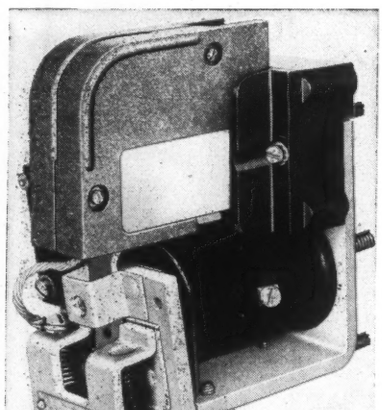
MEETING THE need for an electrical control initiated by changes in fluid pressure, a new pressure-controlled switch has been developed by Mu-Switch Corp. Inc., 380



Pequit St., Canton, Mass. Of standard, single-pole, double-throw type, the switch is furnished with a Type M Mu-Switch rated at 15 amperes 125 volts alternating current to 2 amperes 600 volts alternating current, or one-half hp at voltages up to 460 alternating current. For low-voltage direct current applications, the pressure switch is furnished with a standard Type A Mu-Switch having a maximum current rating of 25 amperes at 28 volts direct current. The pressure-sensitive portion of the switch assembly consists of a metal bellows soldered into a brass tube attached to the metal housing which contained the electric circuit element. This unit can be furnished for operation with a differential of 5 to 15 pounds at nominal ratings of from 10 to 120 pounds per square inch. Pressure chamber is of corrosion and heat-resisting material, and the unit can be safely operated at temperatures up to 300 F.

Magnetic Contactors

FOR USE WHERE space is limited in applications such as machine tool control, marine and mine control, and similar severe-duty uses, a new type M d-c single-pole magnetic contactor has been announced by Westinghouse Electric Corp. Available in rear or front-connected units, the contactor is entirely assembled on a formed frame. Applications to which the small frame contactor is limited include those in which the coil voltage and the voltage of the



circuit being interrupted do not exceed 250 volts. The deep frame contactors, which provide greater winding space for the operating coil, are suitable for voltage up to 600 volts.

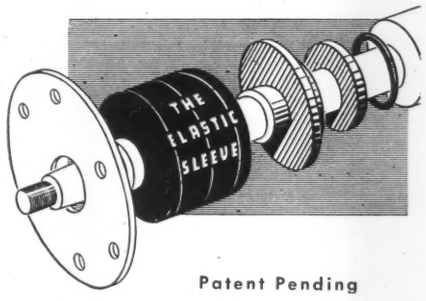
Grinder Coolant Filter

FOR CLEANING grinder coolant and similar solid-bearing fluids, a new filter has been introduced by Cuno Engineering Corp., Meriden, Conn. This "Coolant-Kleen" filter has a replaceable (bag-type) filter element, mounted on a screen spacer to provide a large filtering area (1000 square inches) for full flow. When replacement of the bag is necessary, this is accomplished in less than five minutes, by loosening a screw clamp which opens the filter. The dirty element is discarded and the accumu-

lated grit emptied from the sump. A clean bag is easily installed. The filter can be applied to any type of grinder, and is also adaptable to any machine using a coolant or cutting oil. To install the complete unit, only two flexible hose connections are necessary. No extra pump, electrical work, plumbing, valves or by-passes are required.

Elastic Sleeve Seal

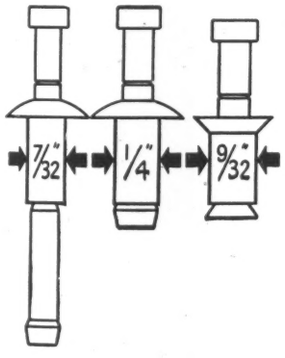
SEALING OF rotary shafts in centrifugal, rotary, reciprocating and any other pumps is accomplished by a new elastic sleeve seal introduced by Temperature Control Devices Inc., New Haven 15, Conn. According to tests, the



Patent Pending

seals work equally well on bent, pitted, or slotted shafts and eliminate springs and shaft glands due to the new oil-resistant elastic material now being used as the body of the seal. The seal bearing of the sleeve seal is located at the source of oil supply.

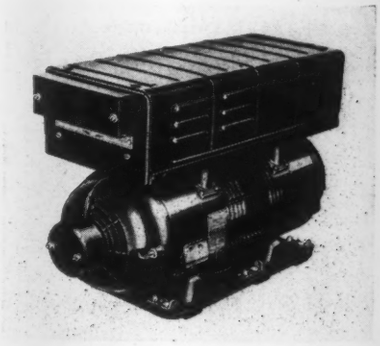
Large Diameter Blind Rivets



TO MEET THE need for larger diameter blind rivets, Cherry Rivet Co., 231 Winston St., Los Angeles 13, is offering three new diameters: 7/32, 1/4 and 9/32-inch types. These rivets are available in the self-plugging, regular hollow and pull-through hollow types; in modified brazier and 100-degree countersunk heads; in A17ST or 56S aluminum alloy, and in steel. To install these larger rivets, a pneumatic-hydraulic rivet gun is also being produced, operating on from 75 to 90 pounds air-line pressure.

D-C, A-C Inverters

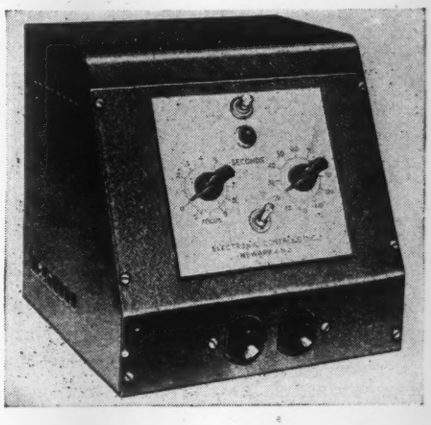
INTRODUCTION OF the first of a series of d-c a-c inverters has been announced by Jack & Heintz Inc., Cleveland 1. Reduction in weight accomplished by use of new lightweight metals, simplified design, elimination of heavy cables and complicated electrical connections are some of the advantages of the new inverter. The unit provides a continuous source of 400-cycle, 115-volt power for use in aircraft applications, with particular reference to radar. It



is of the motor-generator, two-bearing type, complete with control box. Motor is a 4-pole, shunt machine, with a series field for quick starting at low current, and has two interpole windings. Self-ventilation up to 35,000 feet altitude is provided by the mixed-flow fans mounted on each end of the rotor shaft. Airflow from each fan cools the direct and alternating-current sections separately, with a partial diversion of air to cool the control box. Filters installed in the control box keep the conducted and radiated radio interference at a low value, and minimize the alternating-current ripple at the input terminals.

Electronic Interval Timer

FOR APPLICATIONS requiring accurate circuit timing such as in photography, lithography, blueprinting, drying ovens, heat treating, machine tools, etc., a new electronic timer has been announced by Electronic Controls Inc., 44



Summer Ave., Newark 4, N. J. Time range is from 1 to 120 seconds in increments of one second. Two dials are provided: One calibrated in single seconds, the other in 10-second steps. A pilot light, toggle on-off switch and a push-switch are included. Timing two circuits simultaneously is permitted by a double receptacle. Contacts are normally wired single-pole, double-throw with double-break, and are rated at 25 amperes, 35 volts direct cur-

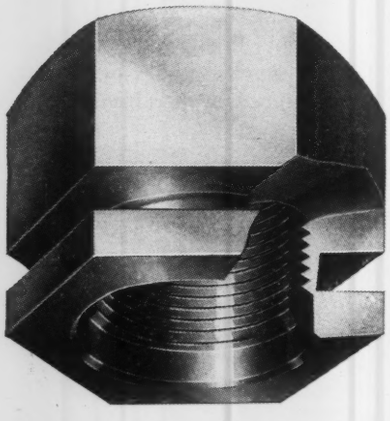
rent, 25 amperes, 125 volts alternating current and 10 amperes, 230 volts alternating current. Contacts can be wired double-pole double-throw at lower ratings. Size of cabinet is 8 x 8 x 8 inches. The unit is compact and is supplied for 115 volts alternating current operation.

O-Ring Hydraulic Seals

HYDRAULIC SEALS of O-ring type used on wartime hydraulic systems for actuating cylinders, valves, landing gear struts, and pumps, are now being offered for diversified peacetime applications by Plastic & Rubber Products Inc., 3110 Oak Ridge Drive, Dayton 7, as a result of a license arrangement with Niels A. Christensen, inventor and holder of the patent on these seals. Consisting of a round, cross-section, precision-molded, synthetic-rubber ring, the seals are installed in a rectangular groove, cut in a hydraulic piston, or in the end cap of a hydraulic cylinder. They seal the pistons and piston rods at high pressures, and are easy to install.

One-Piece Lock Nuts

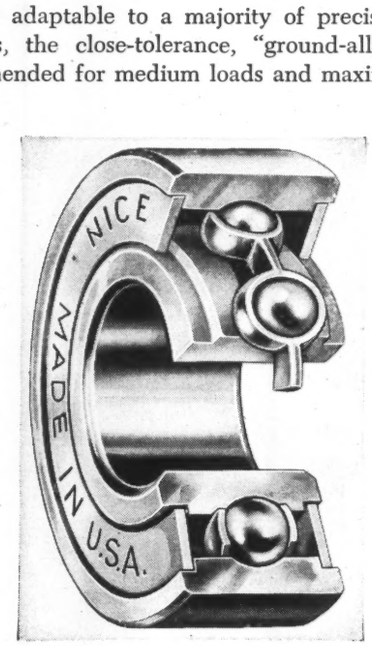
ALL-METAL LOCKNUTS that can be plated or painted and are not affected by extremely high or low temperature applications have been announced by Faultless Caster Corp., Evansville, Ind. The nuts are being produced in both steel and brass, National coarse and fine thread series, in a full range of sizes. Conegrip locking feature includes



a cone diameter finished larger than the lock-washer inside diameter. Thus when the unit is tightened against a surface the thin section joining the cone and washer breaks, the cone is compressed inside the washer, and pressure around mating bolt threads is increased as the cone is wedged within the locking element, producing locked unit.

Inch-Size Precision Bearings

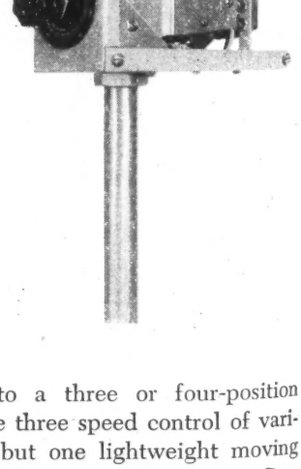
PRECISION RADIAL bearings in inch-size are being added to the line of bearings offered by Nice Ball Bearing Co., 30th and Hunting Park Ave., Philadelphia 40. Particularly adaptable to a majority of precision bearing applications, the close-tolerance, "ground-all-over" units are recommended for medium loads and maximum speeds



in the neighborhood of 3000 to 5000 rpm. Where smaller sizes are involved and in instances of intermittent service, high speeds may be considered. This Series 1600 bearing incorporates one-piece inner and outer races. A ball retainer, or separator, is also included in all the new series, which construction reduces ball friction and increases range of allowable speeds. Retainers are of two-piece type, designed for minimum ball contact friction, and the balls employed are of close tolerance, highly polished, chrome alloy steel. The bearings are available double shielded, with one shield or without shield, and, with the exception of the double shielded units which are grease-packed as standard, can be furnished with or without grease packing.

Temperature Control Switch

TEMPERATURE CONTROL switches, known as Model E, are available from Burling Instrument Co., 253 Springfield Ave., Newark, N. J., in one-switch, two-switch or three-switch models. The three-switch model is recommended by the company for use where the load is divided into three parts; where one is used for controlling, one as a high limit, one as a low limit; to give

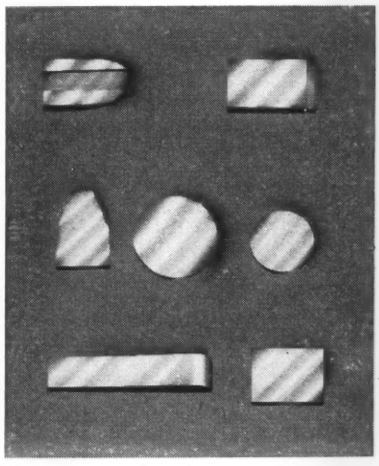


definite steps or positions to a three or four-position diaphragm motor; and to give three speed control of variable-speed motors. Having but one lightweight moving part, the switch has the following characteristics: Cor-

rosion and heat resisting tube, dial pointer for setting, locking screw for temperature setting, and increased adjustable range up to 700-1000 degrees (in some cases up to 1200 degrees). An adjusting screw is provided on each switch so that the differential between the two switches and the three switches can be set at any desired point. Maximum differential between switches is approximately 150 degrees for the two switches of the E-2 (two-switch model) or any two switches of the E-3. Operating differential is plus or minus ¼ to plus or minus 25 degrees.

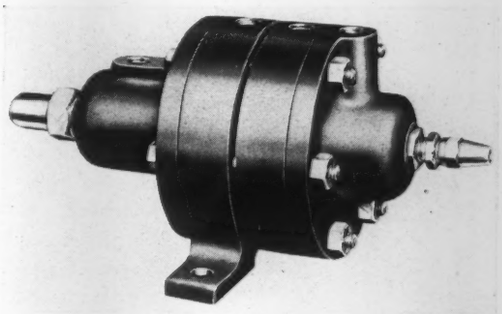
New Series Electrical Contacts

ELECTRICAL contacts from silver tungsten and silver tungsten carbide are offered in the new series of Gibsiloy materials recently developed by Gibson Electric Co., 8355 Frankstown Ave., Pittsburgh 21. Contacts made from these materials offer high current carrying capacity, good nonwelding characteristics and long life. Made by a special process from metal powders, the contacts are offered in combinations ranging from 10 to 80 per cent tungsten in the silver tungsten series, and from 20 to 80 per cent tungsten carbide in the silver-tungsten series, and from 20 to 80 per cent tungsten carbide in the silver-tungsten carbide series, with hardnesses from 80 to 100 Rockwell B.



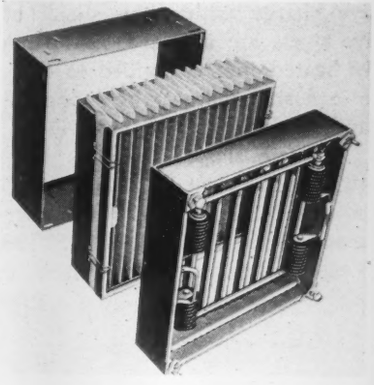
Versatile Totalizer

TYPE F TOTALIZERS—pilot-operated, pneumatic relays—can be used to regulate and to add or subtract loading pressures received from external sources have been developed by Hagan Corp., Hagan Bldg., Pittsburgh. In a control system, the function that the totalizer performs as a regulator depends upon the manner in which the loading pressures are applied to the several diaphragms of the unit. The totalizer requires a source of compressed air at substantially constant pressure for its operation. As such an element in a control system the totalizer may add or subtract loading pressures, average two or more loading pressures, act as a selector of loading, respond to loading pressures sequentially, produce anticipating or derivative action, operate as a safety relay, act as a pneumatic stop for diaphragm-operated valves, and invert loading pressures. In other words, the totalizer may be used in connection with a measuring flow element and a power unit to regulate fluid flow, temperature, pressure, level, speed, or any other physical condition that can be transformed into a loading pressure as an indication of magnitude. Standard diaphragm assemblies are available to receive as many as seven different loading pressures. Diaphragms can be furnished in several sizes for operation at pressures from 1-inch water column to 60 psi.



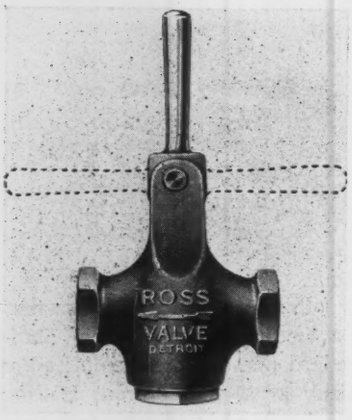
Electronic Air Filter

LATEST ADDITION to the line of electronic air filters produced by American Air Filter Co., 125 Central Ave., Louisville 8, Ky., is the Electro-Airmat in which the collector element is an electrostatically charged Airmat paper. When an electrostatic charge is applied, this paper—a cellulose product composed of a number of plies of porous, tissue-like sheets formed of short cellulose fibers in "jack-straw" arrangement—separates and each individual ply becomes a collecting electrode, attracting and holding dust and smoke particles. The paper is also a mechanical filtering media. When power is off for any reason, it affords protection against infiltration of dust due to "stack effects" in air conditioning systems. When the paper has accumulated its dust load, it is removed and replaced



with clean material by means of turning a crank in a mechanical loader which automatically folds the paper into the serrated base section of the filter unit. The power pack operates on a 110-volt, 60-cycle, single-phase current. Total power consumption is approximately 220 watts at 110 volts, including transformer losses in the power pack, etc.

Air-Operated Valves



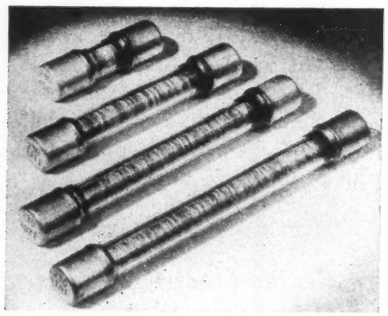
ADDITION OF a shut-off valve to its line of poppet type, air-operated valves has been announced by Ross Operating Valve Co., 6485 Epworth Blvd., Detroit 10. Primarily designed for use in air lines, it is also recommended in gas and low-pressure liquid lines. Five outstanding features of the new valve are: Full pipe area for full flow, quick action, self-locking in both closed or open position, positive shut-off with line pressure providing leakproof seal, and visual indication with the shut-off lever to show whether valve is closed or open. Made of noncorrosive metals, the valve is produced in four standard sizes: ¼, ⅜, ½ and ¾-inch.

Explosive Blind Rivets

ESPECIALLY adapted to meet needs of peacetime mass production, an improved explosive rivet has been announced by E. I. du Pont de Nemours & Co., Wilmington 98, Del. The rivet is fastened in place by firing a small explosive charge within the shank of the rivet. After explosive rivets are in place, heat from the tip of an electrically heated iron is applied to the rivet heads. This fires the explosive charge within approximately two seconds, expanding the shank of the rivet to fill the hole completely. A barrel-shaped head is formed on the "blind" end to lock the rivet in place. While the rivets are offered in 1/8, 5/32 and 3/16-inch diameters, they will be produced later in additional sizes. They are available now in several aluminum alloys, brass, copper, mild steel and Monel metal.

Selenium Rectifier Stacks

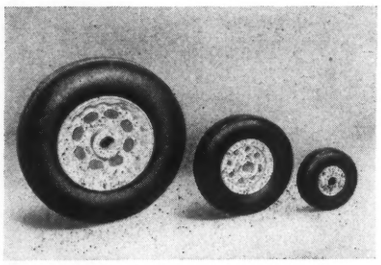
NO LARGER AROUND than a fountain pen and constructed like a cartridge fuse, the high-voltage selenium rectifier stacks developed by Federal Telephone & Radio Corp., 67 Broad St., New York 4, may be installed quickly and easily. Electrical connection is made through heavy silver-plated ferrules at each end of the glass tube. Ferrules are of a size to permit mounting in 30-ampere fuse clips unpolarized or polarized by addition of a simple member to the fuse clip assembly. Designed for operation in high



ambient temperatures, the rectifiers are available in several tube lengths and in various voltages up to 4000 volts.

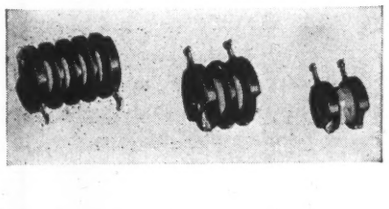
Split-Type Industrial Wheels

CAST ALUMINUM industrial wheels that are easily mounted to solid rubber tires, without the use of tools, have been announced by Aircraft Mechanics Inc., Colorado Springs, Colo. The two wheel halves are designed to fit readily into the tire and become seated securely as the wheel bolts are tightened. In the accomplanying illustration three wheels are shown, two of which utilize wheel bolts and one which is of a new design. The wheel, pictured at right, utilizes a wire spring retaining lock for retention of the two wheel halves.

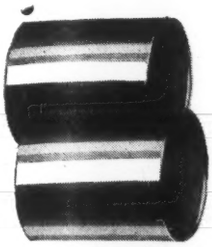


Bobbin-Type Resistors

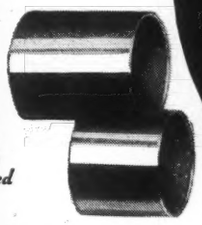
FOR USE IN industrial applications, three new units rated at 1, 2 and 3 watts at 80 C ambient have been added to the line of wire-wound bobbin-type resistors



produced by Sprague Electric Co., Resistor Division, North Adams, Mass. They are wound with ceramic-insulated resistance wire on molded, high-temperature plas-

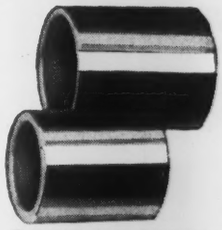


SHEET BRONZE
Plain or graphited



BRONZE ON STEEL
Plain or graphited

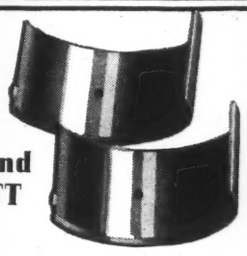
There is ONE RIGHT BEARING for each Application



CAST BRONZE
Plain or graphited

BRONZE and BABBITT

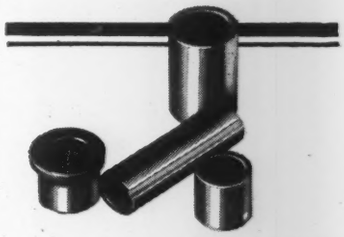
Johnson Bronze *helps* Manufacturers *make the* RIGHT *choice*



STEEL and BABBITT

One easy way to improve the performance of any motive unit is to check up on the bearings. Determine if they are the right type . . . correct in design . . . properly installed. See if they reduce friction to the very minimum . . . eliminate vibration . . . perform quietly for the longest period of time.

The easiest way to determine this is to call in a Johnson Bronze Engineer. Permit him to review your applications . . . to study the operating conditions. As we manufacture *all* types of Sleeve Bearings, we base our recommendations on facts . . . free from prejudice . . . backed by more than forty years exclusive bearing experience. You will find a Johnson Engineer as near as your telephone. Why not get together TODAY?



LEDALOYL
Self-Lubricating

JOHNSON BRONZE CO.
525 S. MILL STREET
NEW CASTLE, PA.

ATLANTA . . . BUFFALO
CAMBRIDGE, MASS.
CHICAGO
CINCINNATI
CLEVELAND
DALLAS
DETROIT
KANSAS CITY

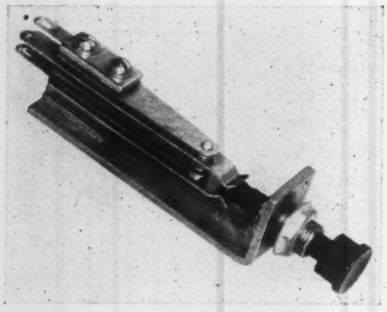
JOHNSON BRONZE
SLEEVE BEARING HEADQUARTERS

LOS ANGELES
MINNEAPOLIS
NEWARK
NEW YORK
PHILADELPHIA
PITTSBURGH
SAN FRANCISCO
ST. LOUIS . . . . SEATTLE

tic forms and are impregnated for protection against tropical humidity conditions. Resistance tolerance is available from ± ½ to ± 5 per cent. Standard temperature coefficients wound with nickel-chromium wire is 0.017 per cent. Lower coefficients can be provided by use of special alloy wires. Maximum permissible temperature, ambient plus rise, is 150 C. Type RX3 (9/16 x 15/32-inch) carries a maximum resistance value of 100,000 ohms when wound with 1.5 mil ceramic-insulated wire or 25,000 ohms with 2.5 mil wire. Type RX4 (¾ x ¾-inch) has a maximum 300,000 ohms with 1.5 mil wire and 75,000 ohms with 2.5 mil wire. Type RX5 (¾ x 1 inch) carries 500,000 ohms with 1.5 mil wire, or a maximum of 125,000 ohms with 2.5 mil wire.

Heavy Duty Switches

DESIGNED FOR circuits carrying heavier currents than usually found in communication and signal systems, Series 5300 and 5300X, standard duty and extra-heavy duty, push switches have been developed by Donald P. Mossman Inc., 612 N. Michigan Ave., Chicago. The standard duty switch is available in 5 amperes, 115 volts, al-



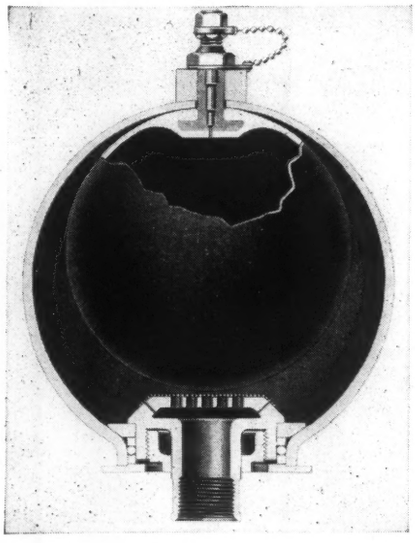
ternating current (non-inductive), and the extra heavy duty in 10 amperes. The switch shown in the accompanying illustration is built with 1 Form C, make-break, and 1 Form B break locking. It is also available in a nonlocking position. Both switches are nickel plated and have phosphor bronze springs with fine silver contacts, plungers of hard rubber and red or black plastic knobs fastened to the plunger with a nickel-plated set screw. Overall dimensions of the switch shown are ¾ x 1 x 4¼ in.

Black-Light Lamp

DEVELOPED BY The Westinghouse Lamp Division, Bloomfield, N. J., a fluorescent lamp producing unseen ultraviolet rays was designed chiefly to improve dial lighting and for radio set beautification. The tubular lamp is a simplified, miniature version of the fluorescent tube, but in place of phosphors special black light phosphors coat the inner surface of the radio panel lamp. It will be used with a special glass mask which blocks out stray visible light present even with black light phosphors but which permits invisible black light to stream through. Under average usage, the new six-watt lamp should burn five years. Its luminous length is 7 inches and its overall length is 8½ inches, while the diameter is ⅝-inch.

Burstproof Accumulators

HYDRAULIC ACCUMULATORS, announced by Greer Hydraulics Inc., 454 Eighteenth St., Brooklyn, 15, are burstproof because they are so designed that when the internal pressure reaches 300 per cent of the rated working pressure, the neck of the shell expands and permits oil to leak out without danger. Disassembly of accumulator is impossible until air is first released which is an additional safety feature. Light in weight and simple in design, the accumulators have a one-piece shell of uniform thickness. The one-piece fully enclosed synthetic



rubber bag has an operating range between −65 and 160 F. Volumetric efficiency is 97 per cent. A 5-inch accumulator for operation at either 1500 or 3000 psi is now available, and 7½ and 10-inch sizes can be furnished specially.

Selenium Rectifiers

SELENIUM RECTIFIERS as produced by Radio Receptor Co. Inc., 251 West Nineteenth Ave., New York 11, which were announced on Page 165 of the December 1945

issue, were, due to an error, illustrated by an incorrect cut. The Radio Receptor Company's rectifier is shown in the accompanying illustration.

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Here's a new Dow plastic that gives you the rare opportunity to put your plastics plans to work—RIGHT NOW!

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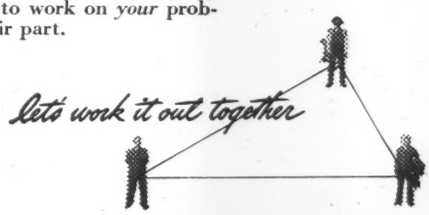

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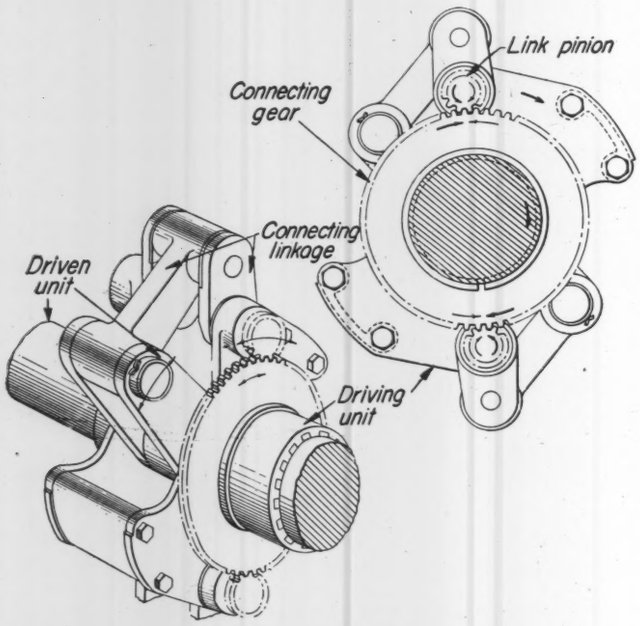
Noteworthy Patents

Eliminates Pulsations

AN IMPROVED type coupling which includes means for damping or eliminating vibrations normally transmitted by prime movers is shown in the accompanying illustration. Covered by patent 2,386,097 assigned to the



Dynamic balance between driving torque and centrifugal force acting upon a pair of links provides resilient coupling

Briggs Mfg. Co., the coupling will transmit at substantially uniform speed the pulsating torque developed by internal combustion engines and is particularly adapted to such engines where use of a heavy flywheel is impractical.

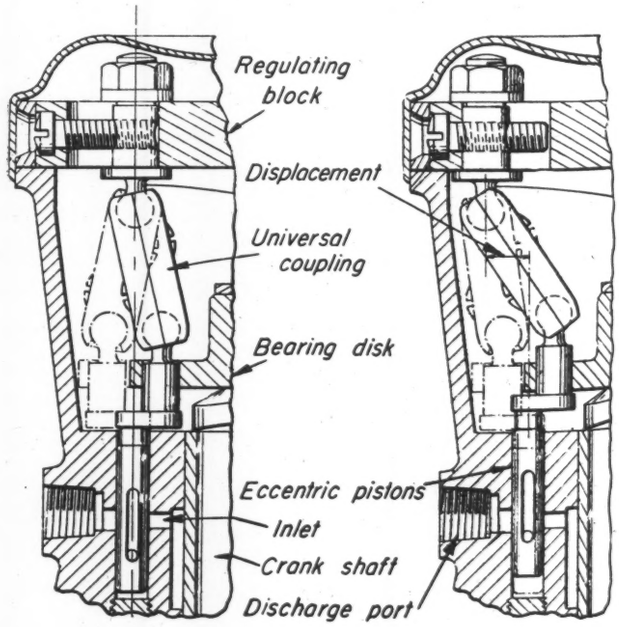
Of simple, compact and sturdy construction, the coupling eliminates all rubber, springs and like damping members in favor of centrifugally-actuated linkages. That shown in the illustration is designed especially for coupling the propeller and engine of aircraft. The coupling helps eliminate failures of propellers and reduction gears and in addition permits the use of lighter construction.

In operation, when rotative power or torque is transmitted from the driving end to the driven, the effort exerted by the driving unit on the pinion shafts pulls the connecting linkages into straight lines, transmitting the torque to the driven unit. However, the effect of centrifugal force on the links and connecting pins as the engine speed increases tends to pull the links outwardly toward positions shown in the illustration. Positions of the links, therefore, depend upon the dynamic balance between the forces of the driving torque acting upon the linkages tending to pull them into alignment and centrifugal force tending to pull the linkages outward. When this balance is reached, the operation of the coupling becomes substantially uniform at a mean link position between the extremes. Vibrations or pulsations which occur are resisted by the inertia of the links and are absorbed in the process of changing the angular displacement between the driving and driven shafts. Resilient transmission of the driving force is thus effected.

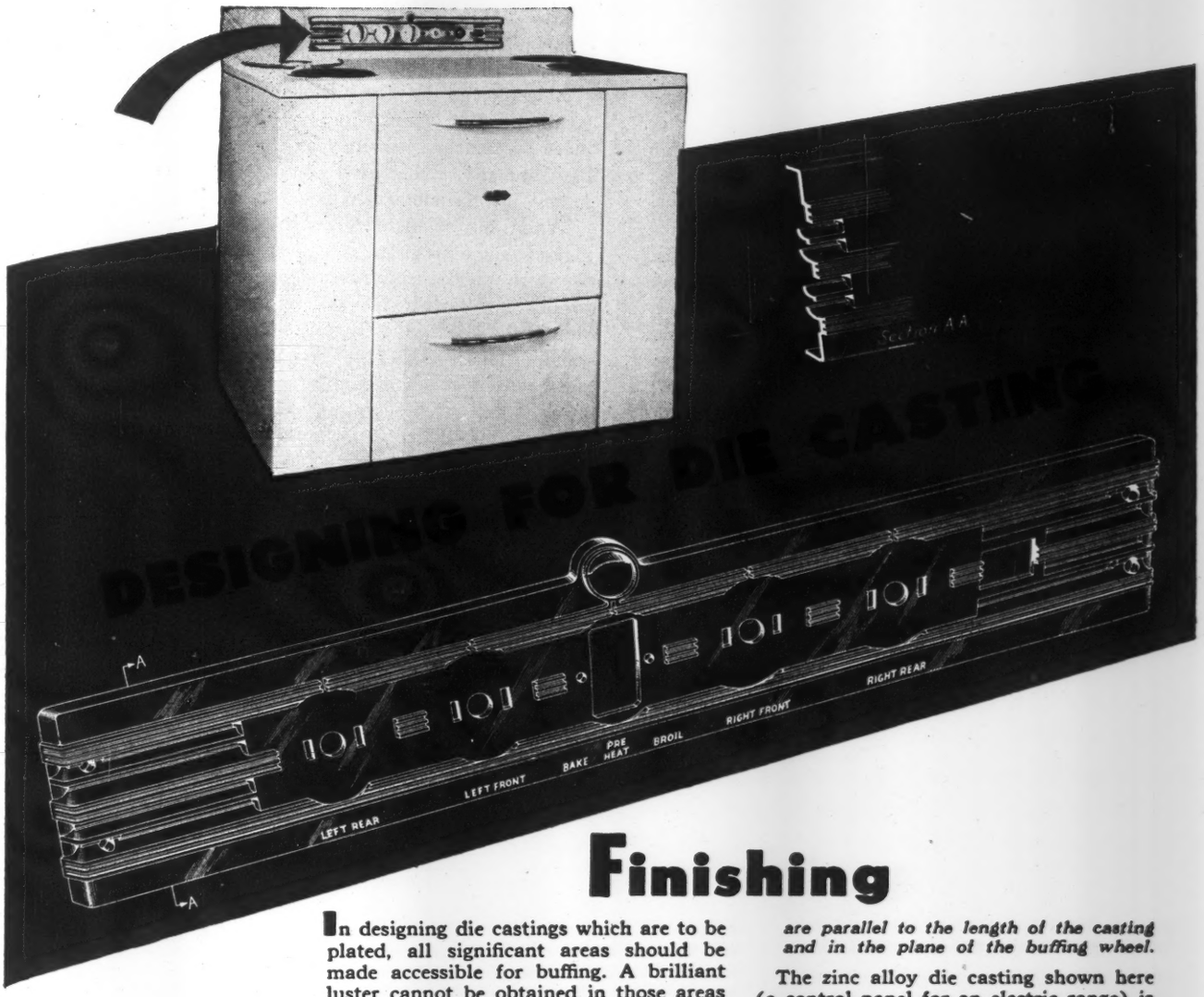
Constant relative position is retained between the two link mechanisms by means of driving link pinions which mesh with a free connecting gear mounted on the driving unit. The moment of inertia of the links can be regulated as desired by increasing the weight and shape of the side flanks of the geared link arms. Both driving and driven shafts to be connected by the coupling must be in fairly exact straight-line relationship for successful application.

Adjustable Metering Pistons

COVERED by patent 2,369,345 recently assigned to Nathan Manufacturing Co., the mechanism shown in the accompanying illustration is designed to deliver predetermined exact amounts of a fluid or maintain certain desired pressure conditions in one or more hydraulic circuits for spinning pumps, mechanical lubricators, metering systems, etc. Individual means are provided for changing the stroke of the piston for the purpose of regulating the fluid discharge from any or all pumping units used. Sequential discharges from the pistons can be obtained to



Hydraulic piston actuating and adjusting mechanism provides a highly accurate means for making a wide range of pressure and flow adjustments



Finishing

In designing die castings which are to be plated, all significant areas should be made accessible for buffing. A brilliant luster cannot be obtained in those areas which the buffing wheel cannot reach. This — and the following salient facts — should be considered when castings are to be plated:

1. *Deep or narrow recesses are difficult to plate and they tend to entrap the buffing compound.*
2. *Generous radii in re-entrant angles prevent the necessity for applying excessive thickness of plate to meet minimum coating requirements at the radii.*
3. *Sharp outside edges, corners and points should be avoided because deposits on such areas tend to be rough and brittle.*
4. *Convex surfaces are easier to plate than flat surfaces or deep concave areas.*
5. *Where beads are used for decorative effects, buffing is facilitated if the beads are parallel to the length of the casting and in the plane of the buffing wheel.*

The zinc alloy die casting shown here (a control panel for an electric range) is a good example of designing for ease of finishing. The decorative beads run parallel to the length of the casting and the spaces between the beads are finished in black enamel to contrast with the overall plating of the part. The lettering below the control knob openings is recessed and also finished in the contrasting black enamel. All recesses are shallow and all significant areas can be reached by the buffing wheel.

Additional data on designing for ease of finishing will be found in our booklet "Designing For Die Casting". To insure that you will get the most from your die casting dollar, ask us—or your die casting source—for a copy of this booklet.

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distribute the loading evenly or to permit combination of discharges into a substantially constant fluid flow.

Compact and simple in design, the pumping mechanism is suitable for producing high pressures and can be operated at high speeds if necessary. A regulating block or adjustable ball pivot is mounted directly on a screw within a radial slot to provide a fixed pivot point for one end of a universal coupling which retains the piston. By movement of the adjusting screw, the "displacement" can be varied to provide a piston stroke from zero to maximum.

One or more pumping units can be utilized to achieve a flexible arrangement serving many circuits. Each eccentric piston is mounted so as to be offset in the same direction as the driving or driven crankshaft. By positioning the grooves in the pistons, the radial adjustment slots, the inlet passages, and the discharge ports in proper relationship, any desired sequence of operation between the several pistons used can be obtained.

High-Speed Index Is Silent

COVERED by patent 2,386,432 recently assigned to the Gleason Works is a mechanism for indexing work being machined. The design shown in the accompanying illustration is primarily intended to be employed on machines designed for producing gears. Main objectives achieved by the new design are positive indexing control eliminating inaccuracies, shockless operation at high speeds, and substantially noiseless performance. A wide range of adjustment readily affords operation at maximum efficiency for almost any number of stations used.

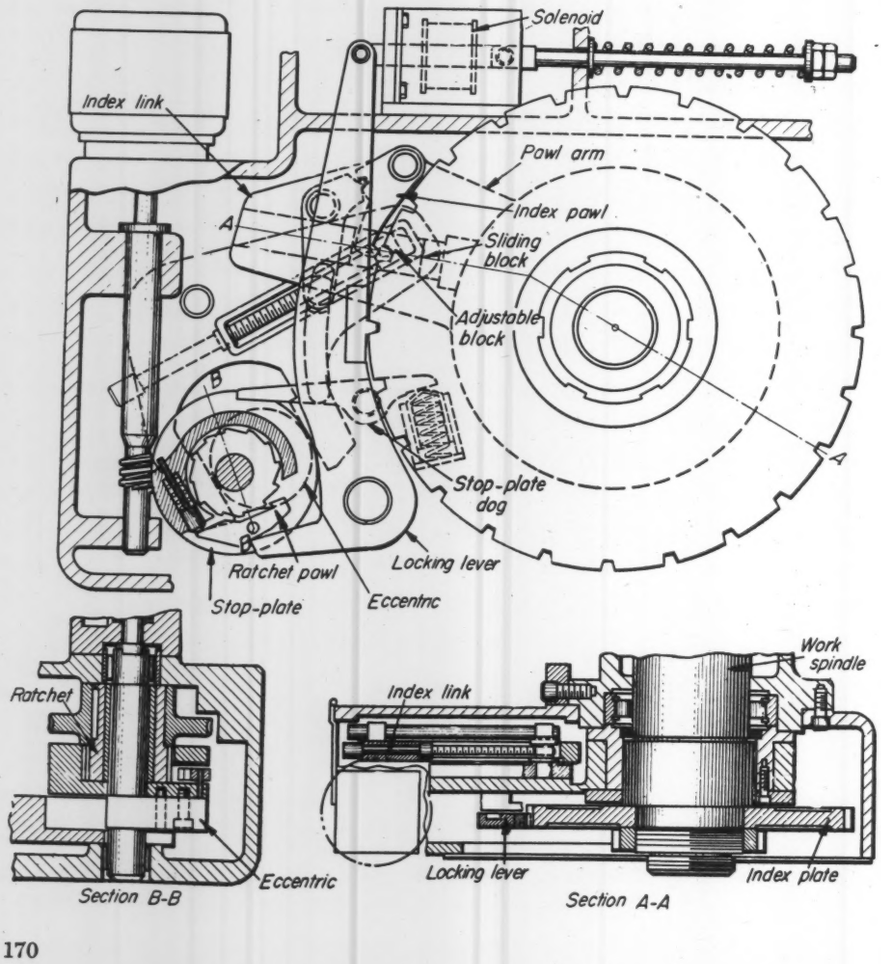
As shown in the plan view, the mechanism is in locked position. The locking dog lever holds the index plate in place by means of its actuating coil spring. Both the index pawl and the ratchet pawl are retracted and the stop-plate is held by the stop-plate dog.

When the solenoid is energized, the locking lever is rocked about its pivot, releasing the index plate. Simultaneously, as the lever rocks, it imparts an opposite motion to the index pawl by means of an arcuate slot on the underside of the lever which actuates the pawl through an intermediate lever. This action engages the tooth of the index pawl with a notch of the index plate. With the locking lever in full release position, the tail of the ratchet pawl engages the ratchet under spring loading.

Continuously powered by means of a motor and worm drive, the ratchet wheel thus transmits through the pawl counterclockwise rotation to the stop-plate. Rotation of the stop-plate simultaneously operates the eccentric to which it is attached, thus swinging the index link. This motion rocks the pawl arm about the axis of the work spindle carrying with it the index plate. By means of the positioning screw provided for the adjustment block, the index pawl can be made to swing over one or more stations to align the notch of the index plate held by the pawl exactly with the tooth of the locking lever.

De-energization of the solenoid at this point swings the locking lever into engagement with the index plate, releasing both the index pawl and the ratchet pawl. Just prior to full release of the ratchet pawl and subsequent locking of the ratchet, rotation of the stop plate swings the pawl arm back to initial position, resetting the mechanism. The stop-plate dog automatically operates to prevent reverse movement of the plate during the inactive cycle.

Unlike many indexing mechanisms, the pawl which drives the index plate is completely engaged before rotation begins. The eccentric drive operates to provide a slow start and stop movement, eliminating inaccuracies and noise created by shock which often accompanies high-speed indexing.



Left—A novel link motion, which engages an indexing pawl while the notch of the index plate is stationary, provides silent, accurate high-speed indexing

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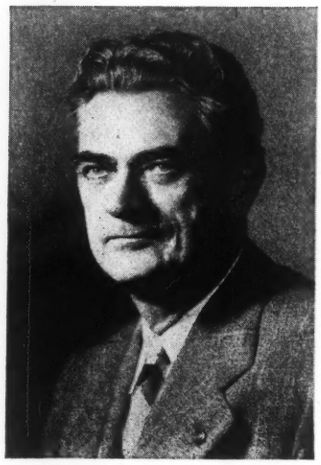

L. Ray Buckendale

MEN...of...machines

H. C. McCASLIN, a veteran of twenty-five years of automotive and truck engineering, recently was elected vice president in charge of engineering and a director of Kaiser-Frazer Corp. He previously had been connected with Willys-Overland Motors Inc., where he served as chief engineer for six years. In this position he played an important role in the development of the military jeep. Prior to 1930 when he joined Willys, he was an assistant chief engineer in the development of trucks for the Stewart Motor Truck Co. Mr. McCaslin's background, covering all types of automotive engineering, includes considerable experience with front wheel drives, having pioneered in development with the Ruxton Motor Car Co. He is now directing the engineering of the new Kaiser automobile to be produced by the new company, and the Frazer automobile, to be produced by Graham-Paige Motors.

ALBERT W. LAVERS, who has been engaged in farm equipment engineering for more than twenty-five years, has been made chief engineer of the Graham-Paige Motors Corp., Farm Equipment Division. Until joining this company recently, he had been administrative engineer for Harry Ferguson Inc., for two years. Prior to that he has twenty-six years' service with the Minneapolis-Moline Power Implement Co. and its predecessor company. Here he served as chief engineer of the M-M automotive division and had charge of tractor and engine design. He is credited with developing the first tractor to operate on high-grade gasoline. Mr. Lavers is a member of the Society of Automotive Engineers, and the Tractor and Farm Machinery Engineering Activity Committee. He is also chairman of the Tractor War Emergency Committee.

L.RAY BUCKENDALE, a member of the Society of Automotive Engineers since 1919 and particularly active in technical committe work as early as 1923, has become president of the society. As a member of the SAE Ordnance Advisory Committee and the SAE War Engineering Board, he contributed to the development of many heavy-duty trucks and tank-transport vehicles. Mr. Buckendale began with the Timken-Detroit Axle Co. on a part time basis while still a student at the University of Michigan. He has been there ever since, taking part in the development of military ground vehicles in both world wars and serving the automotive engineering field as an analyst

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A *complete* line of mechanical packings: VIM Leather for high pressures, VIX-SYN for higher temperatures or extremely low pressures.

VIM, the "engineered" leather packing, has long been the standard for most hydraulic and pneumatic requirements. A war-born development in the VIM line is the resin-impregnated "V," which resists oil so effectively. There are many special impregnations for the long wearing VIM leather, moulded to all standard shapes.

And now, to complete the line, we've added synthetic rubber packings, especially useful for higher temperatures. VIX-SYN is supplied in homogeneous form, and in fabrication with duck, asbestos and other fibres. Complete engineering specifications are available upon request.

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and administrator. A native of Detroit, he attended its schools before entering the University of Michigan from which he was graduated with a bachelor of engineering degree. While still in school he worked as a draftsman for the University Motor Car Co. and the Demot Car Co., and as a machinist for J. N. Smith, then as a draftsman for Timken-Detroit.

G. G. LANDIS, the new vice president in charge of engineering for The Lincoln Electric Co., is responsible for the design and production engineering on welding equipment produced by the company. He has been connected with this organization for twenty years. After receiving his electrical engineering eductation at Ohio State University, from which he was graduated with a bachelor of science degree in 1922, he worked with several large electrical companies for two years. At this time he resigned to enter the laboratories of the Lincoln company. In 1930 he was promoted to chief engineer. Mr. Landis has to his credit many patents on both arc welding and electric motors, and has contributed numerous articles to the trade magazines. He is a member of the honorary A. S. M. E. medal, awarded by the American Society

♦

KARL PROBST has recently been appointed chief engineer of Reo Motors Inc.

♦

WILLIAM D. GROSECLOSE, formerly hydraulic development engineer with Bendix Aviation Corp., is now chief draftsman with Librascope Inc., Burbank, Calif.

♦

WILLIAM E. KLINGEMAN is the new chief engineer at Precision Welder & Machine Co.

♦

WALTER R. BENNING has become chief engineer of the chassis division, Willys-Overland Motors Inc.

♦

GEORGE A. GREEN, well known in automotive engineering is in Rome, Italy, attached to the State Department and acting as economic adviser to the American Ambassador to Italy. Formerly, he was vice president in charge of engineering of the General Motors Corp. truck and coach division.

♦

CHARLES H. JENNINGS, well-known arc-welding expert and director of welding research for the past nine years at Westinghouse Electric Corp., has been made engineering manager of the welding department. JOHN H. BLANKENBUEHLER is the new manager of arc-welding apparatus.

♦

DON W. RANDOLPH, after having served during the war as Naval Commander in the Bureau of Aeronautics, has returned to Apex Electrical Mfg. Co., Cleveland, as director of engineering. RALPH E. KORTEPETER has been made chief engineer of the company's Cleveland plant while ARCHIBALD H. DAVIS has been named chief engineer at the Holland-Rieger Division plant, Sandusky, O.

♦

LEROY BARRETT, who recently completed his work with the Office of Scientific Research Development, has joined Ellinwood Industries as executive engineer.

♦

OTTO M. JENSEN, an executive for many years of the Peerless Machine Co., Racine, Wis., has been appointed vice president in charge of engineering.

♦

GEORGE C. WEBSTER, formerly connected with the shock and vibration division of the Naval Research Laboratory, has been named special representative for the Engineering Development Co., Washington, D. C.

♦

DON B. WEBSTER, who had been resident engineer at Packard Motor Car Co. for Continental Aviation & Engineering Corp., has been named head of the mechanical laboratory of the Packard organization.

♦

DR. WILLIAM FREDERICK DURAND, professor emeritus of mechanical engineering, Stanford university, received the A.S.M.E. medal, awarded by the American Society of Mechanical Engineers, in recognition of his work in forwarding the design and application of principles of jet propulsion. The Holly Medal, presented for "some great and unique act of genius of an engineering nature", was awarded to DR. SANFORD ALEXANDER MOSS, General Electric engineer of West Lynn, Mass., for his many contributions to the development and application of turbosuperchargers to internal combustion engines.

♦

KARL M. WISE, since 1938 director of engineering, Bendix Products Division, Bendix Aviation Corp., has retired. He joined the company in 1934 after having been director of engineering with Pierce-Arrow Motor Car Co.

♦

SIDNEY M. GAMSU, recently resigned from the staff of Peter Altman, Engineering Consultant, Detroit, has joined the McCauley Corp., Dayton, O., as chief engineer.

♦

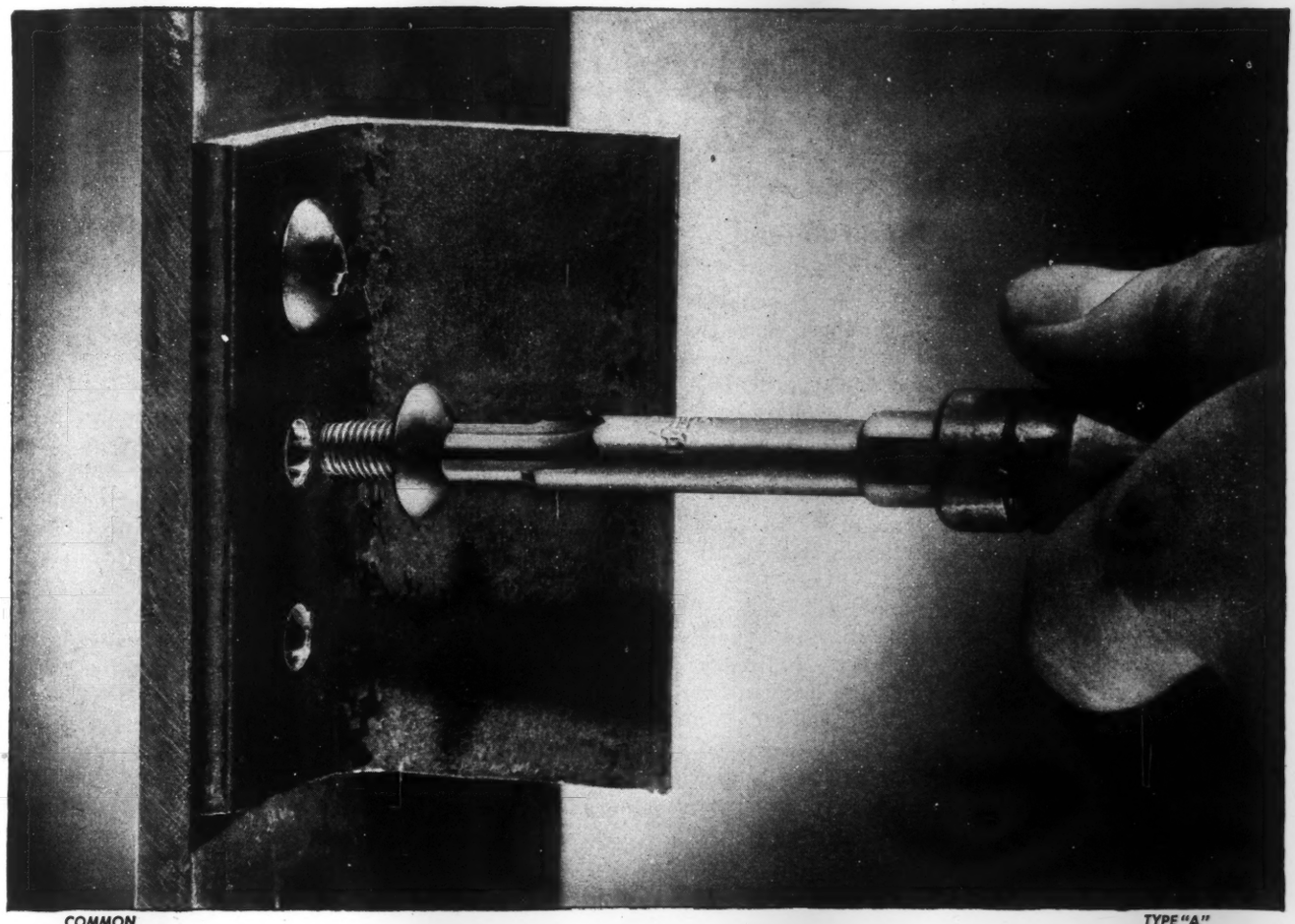
JAMES T. COLIZ, formerly test engineer with Curtiss Propeller Div., Curtiss-Wright Corp., Caldwell, N. J., has been promoted to the position of design engineer.

♦

L. G. SROGI, previously design engineer with Studebaker Corp., has been made senior mechanical engineer with Packard Motor Car Co., Toledo Division, Toledo, O.

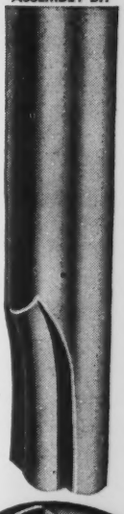
♦

SCOTT B. BARNHARDT is now design engineer, Shovel & Crane Div., Lima Locomotive Works Inc., Lima, O.



COMMON SCREWDRIVER

TYPE "A" ASSEMBLY BIT



There Is No Tougher Test in assembly than the driving of thread-forming screws; especially where the thickness of the metal equals or exceeds the diameter of the screw. This is the critical spot where CLUTCH HEAD'S special features, *of both screw and driver,* challenge point by point comparison... for lower cost, efficiency, speed, and safety.

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- ✓ Positive engagement for definite torque drive; no chewed-up heads; no hazard of slippage to injure manpower or damage materials.
- ✓ The CLUTCH HEAD Lock-On which carries screw and bit as a unit for fast one-motion driving.
- ✓ And . . . an ordinary type screwdriver will service CLUTCH HEADS.

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Design Abstracts

The Motor Coach of the Future

THE motor coach of the future will be longer and wider than at present. How much will depend upon governing regulations and the progress made by the highway engineers in constructing the type of highways we shall need. It is safe to assume, however, that the long-distance bus will be 102 inches wide and forty feet long. In this space the designer can build the comfort so essential to the continued growth of the industry. Forty-one passengers can be seated in 19-inch wide chairs on 40-inch centers. Probably a ladies and a gentlemen's retiring room will be provided.

Present-day gasoline and diesel engines will be obsolete. The power generating equipment may consist of a gas turbine connected to a small, high-speed, glass-insulated, d-c generator. Four small, high-speed electric motors of perhaps 75 hp each may be used to provide flexibility in the final drive. This type of drive will develop high speeds, economically, and provide constant high torque. Speeds in excess of 100 mph *on suitable highways* will be accepted as common, and acceleration will be at the rate of 3½ mph per second.

To keep pace with the higher speeds many new developments will be necessary. New tires are required, of smaller diameter, larger cross section and employing no air. Thus punctures and blow-outs will be rendered impossible. Because of the smaller wheels the brakes will move away from the wheels. Electric brakes will be developed or the polarity of the motors may be reversed for this purpose. The secondary braking system may be hydraulically actuated. Eddy current and water retarders offer other possibilities. Steering will be of the power type, electric, hydraulic, or electric-hydraulic. The driver's only controls will be the throttle and brake. Doors will be hydraulically actuated as will windshield cleaning devices. Defrosting on all glass surfaces will be accomplished electrically. Compressed air will disappear from the vehicle.

An entirely new suspension system will be employed. Leaf springs will be eliminated and suspension will be at or near the c.g., making the bus much more stable.

All passenger compartment windows will be double glazed and the body completely soundproofed. Interiors will be completely air conditioned, and we mean air conditioned, not just cooled. Twenty to twenty-five cubic feet of fresh air will be introduced per seat per minute. This air may contain as much as 132 grains of moisture per pound, which must be reduced to at least 72 grains. This, together with the sensible temperature reduction necessary to human comfort, the load imposed by the passengers, etc., will require about ten tons equivalent refrigeration. All baggage compartments will be air conditioned. This will be provided by exhaust heat, using a vapor system similar to the one now employed by the railroads. Turbine exhaust heat will be ample for this purpose.

Each passenger will have individual draft control similar to that provided in modern passenger transport planes. The inside of the bus will be pressurized, to prevent the infiltration of dust and dirt. All incoming fresh air will be filtered.

Maintenance will be simplified. Electrical connections will be of the push pull type and liquid lines will have a quick-disconnector and sealed joints. Powerplants will be removable in ten minutes, axles in less. All joints and bearings of the control system will be greaseless type. Seat backs and cushions will be readily removable and bound in canvas. The upholstery will be of the envelope type that can be unzipped and cleaned or replaced in a matter of minutes without removing the seat.

The driver will have a public address system for communicating information to the passengers. There will be a multicircuit radio telephone switchboard, entirely automatic. Any passenger may pick up a phone, without leaving his seat, call any telephone number in the country and carry on a conversation while traveling at more than 100 miles per hour. A multichannel radio receiving set will be installed, with headphones built into the headrest of each seat. Selection of programs will be by means of an individual switch.

An inside destination sign will advise customers of the next town on the route. Selection of all destination signs will be by pushbutton similar to modern car radios. An automatic fire-extinguishing system will be built into the bus. This may be of the CO_2 type, operated by electricity.

It is our belief that the wonderful vehicle just described will do all this at one and one-half cent per passenger mile or very close thereto.—*From a paper by L. H. Smith, vice president in charge of engineering, General American Aerocoach Co., presented at the recent SAE annual meeting in Detroit.*

What's Wrong with Engineering Reports?

IN THE COURSE of engineering progress we have steadily improved the technical caliber of engineers. But at the same time most of them have been given far too little help, either by precept or by example, in making corresponding improvements in the relationship between engineering and the people who should use its findings.

In many cases the engineer's principal means of introducing or explaining his results has been through written reports. The difficulties he has with such reports are typical of those he experiences in all of his contacts with people outside engineering. Concentration on purely technical subjects has made the average engineer an untrained amateur in putting ideas down in clear-cut, understandable language. The unfortunate consequence is that our manner of presentation leads others to infer that we are confused in our engineering thinking.

Let's take a closer look at our engineering reports. They are of two kinds—one to record engineering progress, the

How to Reduce 25 Lubrication Points to ONE!

Illustration shows an installation of an Alemite LubroMeter Centralized Lubrication System on a large stamping press. This system handles either oil or grease—can be designed into almost any type of machine.

By itself, an Alemite System appears to be composed of "metal arteries" and valves. Actually, it's the "lifeline" of a machine—your machine, if you like.

Maybe your machine has 10 lubrication points—or 25, or 40, or 60. With an Alemite System there'd only be *one*—the one central point where the lubricant is introduced. From that *one* point *all* points would be positively lubricated with a metered quantity of grease or oil without *stopping the machine!*

Results like these are common. A huge rotogravure printing press had to be shut down 2 hours daily for lubrication, and bearing failures were frequent. Today, with an Alemite Centralized System, the press is positively lubricated, while in operation, in only 10 minutes per 24 hour day. *And*—bearing failures have ceased to exist.

When you design Alemite Centralized Lubrication into your machines you automatically protect their performance from the dangers of human error. You reduce the number of lubrication points to *one*. You guarantee positive lubrication without "time-outs." You cut repairs to a minimum...lengthen machine life... increase satisfaction. It all adds up to More Productive Time per machine. And that enhances your reputation as a designer.

* * *

Without obligation, have an Alemite Lubrication Specialist demonstrate one or all 4 new Centralized Systems right at your desk with transparent working models. Also, ask for any technical help you want regarding Alemite Systems. Drop a note on your letterhead to Alemite, 1804 Diversey Parkway, Chicago 14, Illinois.

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Only Alemite Combines ALL 3 in Lubrication

1. EQUIPMENT 2. PROCEDURES 3. LUBRICANTS

ALEMITE KEEPS THE WORLD GOING ROUND

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other to present an idea or engineering recommendation. They go to different kinds of people, but each is highly important. Many of us dislike reading reports, let alone writing them. Yet many times they represent the principal end product of months of skillful and creative work. Their contents may be a distinct and improtant contribution to engineering knowledge, and may point the way to significant advancements . . . but what does the average engineering report look like? Well, it is probably a reasonably accurate facsimile of the hundreds of other reports that have been prepared over the last twenty years or so. Outside, it has the same drab cover . . . apparently the duller and less attractive, the better. Inside it is probably reproduced on cheap paper, by means of one of the less satisfactory methods of duplicating. Little attention has been paid to margins, heading, spacing and similar factors of physical arrangement. Yet those very physical characteristics can do much, either to convey the actual importance of the report or, if neglected, to destroy any feeling of value.

But how about the material inside the report? For one thing, there is little help for the man whose time is limited, but who still should be made acquainted with the principal findings reported. Charts and curves generally require considerable study to dig out their significance. Photographs or other illustrations often are insufficiently identified, so that the reader, unless he is an expert, doesn't know what to look for, or what particular point is being illustrated, without studying the entire report. Too much dependence is placed on inference, rather than direct statement, to get the point across. Instead of being pointed up and emphasized, important facts and conclusions are frequently buried in a mass of detail. Little attempt is made to sum up and interpret the overall significance of the findings. Yet the information is valuable, complete and, in many instances, in advance of any published material. But it is too uninviting, and it is too hard work to dig out the important facts.

Nevertheless these same reports are expected to act as our ambassadors in absentia. They represent us. We send them out unmindful of their forbidding countenance, their unkempt appearance, their complicated jargon and their awkward manners. It is any wonder our day in court is not always successful?—*From a paper by J. C. Zeder, chairman of the engineering board, Chrysler Corp., presented at a recent meeting of the Cleveland Section of SAE.*

Ceramic-Coated Turbine Blades

BECAUSE the efficiency of the jet propulsion engine increases with the temperature of the gas in the turbine, problems have arisen with respect to finding materials resistant to ultrahigh temperatures. In 1941, when special attention became directed to the matter of high temperature-resisting metals, 1200 or 1300 F was about the limit which could be attempted with the best materials which metallurgical science could provide. During the years of the war, active research was carried on with the result that the upper limit of gas temperature that was practical was raised some 400 or 500 degrees. This however, should be considered only as a way station, and active search should continue for new alloys carrying the temperatures to still higher levels.

There are at least two other directions in which search may be made for disposition permitting the use of higher gas temperatures. These are the use of ceramic-coated blades and the cooling of the blades.

Ceramic materials in themselves lack the physical properties of strength for use as the sole material of the blade of a gas turbine. But the combustion of a ceramic coating to take the impact of the hot gas, backed by a metal for the needed strength, appears to offer definite hope. The principal problem in such a construction is the finding of a ceramic with a sufficiently high melting point to bond with the metal, and which will have a coefficient of expansion sufficiently near that of the metal to insure against cracking and flaking off under the wide range of temperatures to which the blades are subject.—*From a recent paper by Dr. Wm. F. Durand, former chairman of the division of engineering and industrial research, National Research Council, at the ASME annual meeting in New York.*

Statistics Aid Engineering Judgment

MODERN statistical methods may be used as an aid to engineering judgment in determining the causes of variability in a complex manufacturing process. It has been said that "a statistician is a man who can lead you directly from a preconceived idea to a foregone conclusion". Properly interpreted, this statement contains an element of truth. But it is not the kind of statement which should be made under oath. For while it is the truth and nothing but the truth, it certainly is not the whole truth. The whole truth might be phrased in similar language as follows: Among a given class of preconceived ideas the statistician can tell, with a definite degree of certainty, which subclass constitutes foregone conclusions.

In a particular example on lightning arrester blocks, the preconceived ideas are the variables, in the process of manufacturing, which were thought to affect the electrical characteristics of the blocks. The foregone conclusions are those variables which actually do significantly affect the electrical characteristics of the blocks. The term significantly is used here in an engineering sense—not a statistical sense.

The blocks consist of silicon carbide and a binder, the electrical characteristics of the silicon carbide being the determining factor of fitness for use. Among the known factors which could cause electrical variations are such things as weight, length, and density of blocks; variations in the manufacturing techniques, the character of the raw silicon carbide, and variations in the testing equipment.

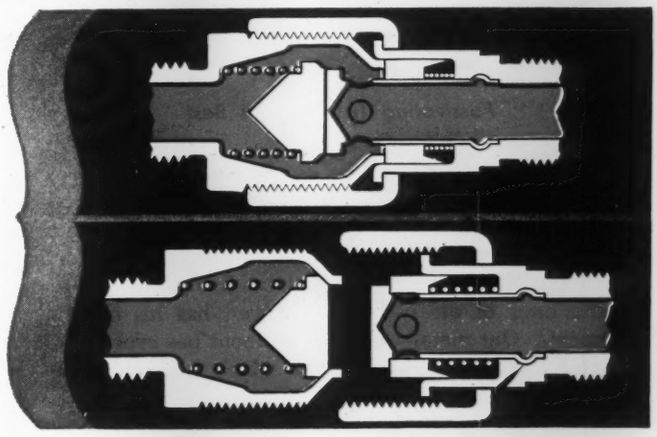
As applied to lightning arrester blocks, statistics helped engineering judgment by verifying that some of the variables which had been thought to affect electrical characteristics actually did so. This led to emphasis of control of these factors at the expense of others which had been thought to affect maximum voltage attained across the block but were found, by statistical analysis, to have a less significant effect. As a consequence of this study a more uniform product is being made and an appreciable reduction in the loss due to scrap during manufacturing has resulted.

Statistical methods are now being further applied to determine superior designs. The main tool being used for this purpose is the designed experiment.—*From a paper by Casper Goffman, Westinghouse Electric Corp., presented at a recent meeting of the AIEE.*

ONE AEROQUIP SELF-SEALING COUPLING*

TAKES THE PLACE OF 2 VALVES

1. Separation and reconnection of fluid carrying lines without loss of liquid or inclusion of air.
2. Simplicity of design by eliminating two manually operated valves together with necessary fittings and connections.
3. Quick acting nut permits disconnection or reconnection in less than a second.
4. Reduces service problems by permitting quick removal and replacement of machine components.
5. Less restriction to flow.



For lines carrying refrigerants, oil, fuels, coolants, hydraulic fluids, and other liquids and gases.

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Detachable Hose Fittings
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Magnesium Die Castings

(*Concluded from Page* 104)

of this in the original design?

MARKINGS: Lettering and insignia always should be cast with the letters sunk into the die and raised on the casting. This not only makes the sinking of the letters into the die easy, but the markings will always be sharp and clear. Raised markings on the die will burn away quickly. In general, a flat-bottomed depression with normal draft on the sides will last longer than a sharp V-notch, and even large emblems or insignia need be only 0.010-0.015-inch deep.

UNIFORMITY OF SECTION: This point is important. It will pay well to go to a lot of trouble to make the sections as uniform as possible. If it is inconvenient to take metal from the front, it is better to sink a "metal saving" punch in from the back to keep the metal thickness uniform. If a high vertical boss is involved, normally cast solid in the case of a sand casting, it may have to be hollowed out by means of a punch brought up from below. It is safe to say that any trouble one must go to in order to attain substantially uniform section thickness will be repaid in sounder and cheaper castings.

CORROSION RESISTANCE TREATMENTS: Ordinarily, chemical treatments and surface finishes are of secondary interest to the design engineer, but magnesium is a material that may succeed or fail entirely because of improper or inadequate surface treatment. There are many chemical treatments for inhibiting surface corrosion. Some are simple, others are complex; some are only mildly helpful and some are really protective, but no known treatment can make magnesium resist corrosion indefinitely. In applications where the surface treatment can abrade off and expose the raw metal to a corroding atmosphere, magnesium should not be used.

Passivating Treatment Is Best

About the best that can be done is to protect the surface by giving it a passivating treatment. Various dichromate mixtures with or without the addition of nitric acid followed by a wash will do a fair job, but the results cannot compare with the better electrolytic treatments. Every manufacturer of die castings, however, has his own pet treatment. Our metallurgical department has evolved and patented an electrolytic method which is highly satisfactory.

If, after giving *any* protective treatment the surface is not uniform in color and later shows gray or white whiskers or is blotched or rough, the die caster should be consulted. It is probably his fault. He may be using a flux or a die wash that is being carried into the casting with the molten metal. A minute bubble of flux, such as sodium bromide, lodged in the body of the castiing can produce an ulcerating sore that will never heal.

Summing up, it may be said that the designer will achieve the most satisfactory results with magnesium die castings if he will:

1. "Let the die do the work" by incorporating in the casting every hole, relief, slit, slot, boss, insert, fin, insignia, lettering and decoration

2. Consult the die maker and die caster early and often

3. Provide for the removal of the smallest practical amount of material at machined surfaces

4. Keep the wall sections as thin as practicable in keeping with strength requirements and strive for uniformity of section

5. Use "generous" or at least "adequate" fillets and avoid sharp corners inside or out unless needed for design

6. Select the most suitable corrosion-inhibiting treatment and if possible make it part of the shop routing procedure

7. Don't ask properties of magnesium that it does not and cannot possess.

(In his concluding article of this two-part series, Mr. Heintz will discuss many unusual design kinks that should prove of considerable help to designers—ED.)

Supersensitive Balancing

(*Continued from Page* 114)

the bed plate has its adjustment through a hole directly in front of it. The purpose of this valve is to maintain a constant balancing speed with line pressure variations which are always present. When a large volume of air is required to maintain the speed of larger rotors, this pressure regulator can be cut out through a valving arrangement on the left side of the air block. Thumb screws are used to hold the Morse taper end of the nozzle in the air block.

Two potentiometers are mounted to the left of the bed plate (*Fig.* 1) and are electrically connected to their respective pickup coils through the slip rings. They serve to attenuate the vibration signal so that the proper drill depth indication on the amplifier meter is obtained. A locking arrangement for these potentiometer settings is provided to keep them from being accidentally shifted. The toggle switch at the right of the bed plate selects either vibration pickup.

Connection of the amplifier, *Fig.* 3, to the balancing unit is through a removable cable and noninterchangeable plugs. The amplifier contains all the necessary controls for switching and adjusting required in the balancing operation. An electrical wave filter in this unit serves a double purpose. It determines the proper balancing speed and also cleans the electrical signal of all extraneous frequencies (other than the unbalance frequencies). This filter is interchangable to permit balancing at any speed. The meter is directly graduated in terms of drill depth.

How Drilling Unit Is Set

Readings obtained on the drill-depth meter are transferred to the drill-depth indicator on the drilling unit, *Fig.* 4. An angular index plate is used when the drilling operation is performed on the side of the rotor, the readings obtained on the angular locating dials of the balancing unit being directly transferred to the drill jig with the reference mark of the rotor lining up with an index mark on the jig.

When the drilling is performed on the periphery of the rotor, a horizontally rotatable V-block is used that can be

Need Answers about Shearing Stainless?

Shear Blades?
What tolerances are recommended on blades for shearing E-S Type 304 Stainless? Can we use the same blades on E-S Type 316?

Fine Perforating?
What is the smallest diameter hole that can be accurately punched in 30-gage E-S Type 302 sheet, and what is the minimum spacing that will not tear between perforations?

Clearance for Blanking?
What die clearance should we use for blanking 6-in. circles in No. 7-gage E-S Type 410 plate?

Clean Slitting?
In slitting and drawing small louvres in E-S Type 321 Stainless, the metal sometimes strings across the slit. How can we overcome this?

Die Changes?
Will E-S Type 430 break out when stamped? Can we use the same dies in stamping E-S Type 430 that we use in stamping E-S Type 347?

Anneal to Trim?
After spinning E-S Type 304 bowls, we want the edge soft enough for trimming and corrugating, without a second anneal. Is this possible?

ask Eastern for the answer when Stainless is the question

Questions like these are "duck soup" at Eastern. Many of the answers are given in the big new catalog, "Eastern Stainless Steel Sheets," but if you have a specific question about cutting or shearing Stainless, be sure to ask Eastern...where your inquiry is welcome. JMLCo-E-B1

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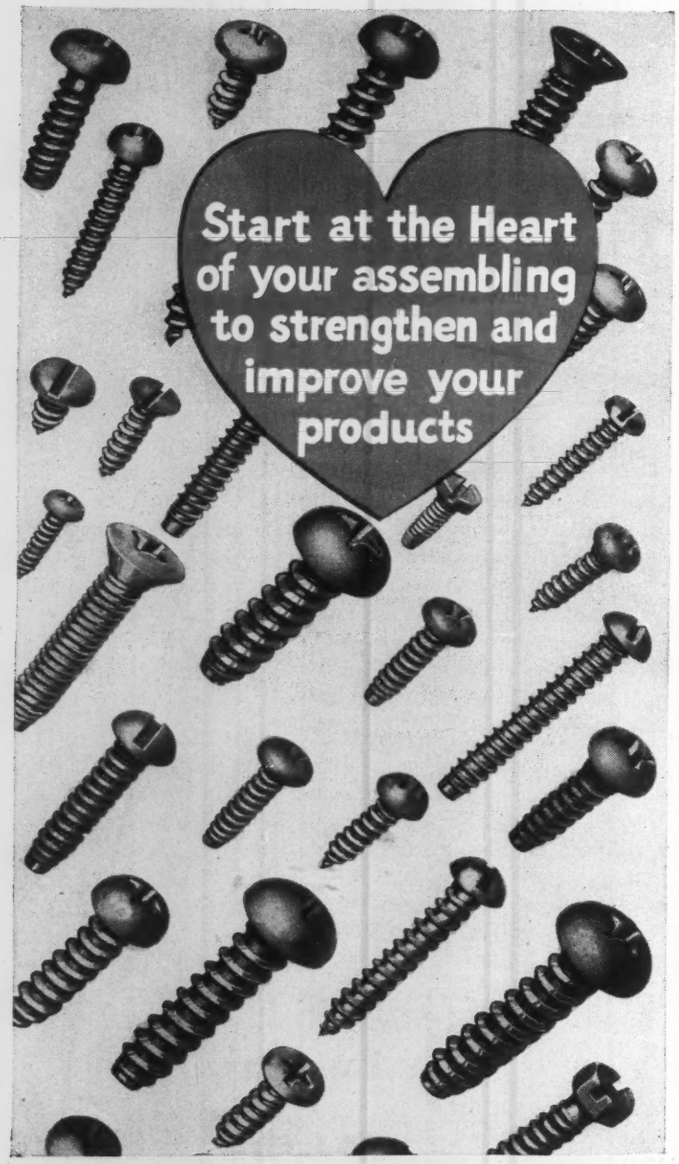

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HOLTITE-Phillips Recessed Head Screws permit safe power driving on jobs previously limited to slow hand driving. Cut fastening time in half . . . strengthen assembly . . . add to the appearance of your product.

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turned 180 degrees to permit drilling on both sides of the rotor. The angular numbers are printed on the periphery of the rotor along with the reference marks by rolling the rotor over a rubber stamp. A vacuum chip remover is provided which sucks the drill shavings up as soon as they are formed. This arrangement prevents any dirt entering the bearings in the drilling operation. A switch, actuated by a cam mounted on the hand lever spindle, starts the motor as soon as the hand lever is depressed. An accurately dimensioned spotting drill is designed to follow the graduations on the drill depth meter, and drill depths to the nearest 0.001-inch can be obtained on the precision drilling unit.

As has been mentioned, the equipment had to be sufficiently sensitive to detect and correct unbalances that produce vibration of 0.000,000,2-inch displacement. There is no direct means for measuring this minute displacement and the quantity is determined by the following method: The spotting drill used has a tip with an included angle of 90 degrees and tapered to a tip dimension of 0.010-inch. The drilled hole will have the shape of a truncated cone. On a brass rotor, a drilling operation of 0.005-inch depth (not unusual for such equipment) will remove:

$$\text{Weight} = \frac{\pi hd}{3}\left(R_1^2 + R_1R_2 + R_2^2\right)$$

$$= \frac{\pi(.005)(4.912)}{3}\left[0.005^2 + (0.005)(0.01) + 0.01^2\right]$$

$$= 4.495 \times 10^{-6} \text{ oz.}$$

density of brass being 4.912 oz/in.^{3}.

On some particular flight instrument gyroscope rotors, where precision balance is required, the unbalance is removed at a radius of 0.562-inch. This is equivalent to an unbalance of

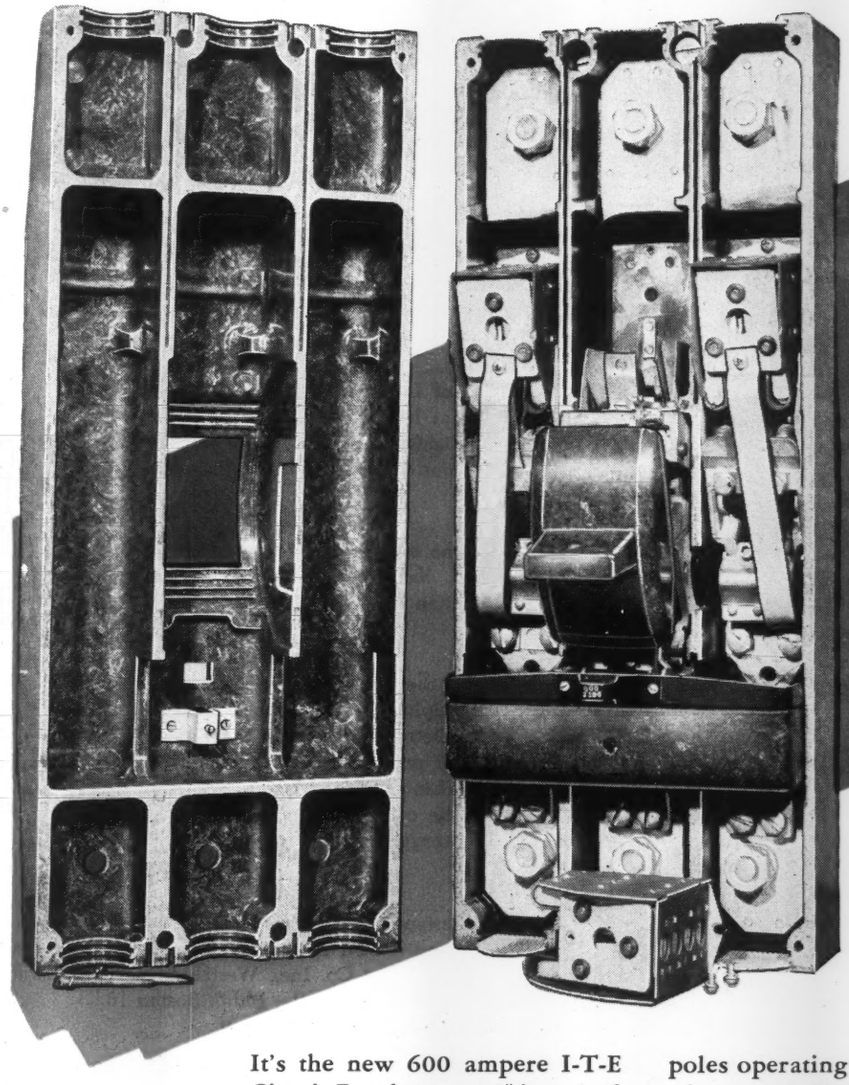
$$0.562 \times 4.495 \times 10^{-6} = 0.000,0025 \text{ ounce-inches}$$

In this system of balancing, where the rotor is freely suspended and the rotational frequency largely exceeds the resonant frequency of the rotor suspension, the axis of spin will coincide closely with the mass center of the rotor. Therefore, the geometric or bearing center will oscillate about the mass center at a radius equal to the displacement of the bearing center from the mass center. This displacement, for a rotor weighing 12.1 oz, is equal to

$$\text{Displacement} = \frac{\text{Unbalance Moment}}{\text{Rotor Weight}}$$

$$\frac{2.5 \times 10^{-6}}{12.1} = 0.000,000,206\text{-in.}$$

In this experiment the unbalance introduced is of pure static nature so that the displacement of mass center from the bearing center is equal on any point along the shaft or any projection thereof. Thus the claimed sensitivity can be readily demonstrated.



BIG ... But NOT TOO BIG FOR CMPC

It's the new 600 ampere I-T-E Circuit Breaker . . . 22″ long and 9″ wide . . . the housing for which was compression molded by CMPC for I-T-E Circuit Breaker Company. Rather large for a molded plastic part, but for CMPC it's just another good job well done.

A phenol formaldehyde material was used for both parts . . . housing and cover . . . because of its low coefficient of expansion, resistance to mechanical shock, freedom from warping, and excellent insulation properties.

The housing is so constructed that the individual circuit phases or poles are encased in separate compartments, the individual poles operating from a common mechanism. This, of course, called for extreme accuracy in die making, and close control in molding.

As usual, the massive molds for this housing were designed by CMPC engineers and fabricated in the CMPC tool room. Molding large plastic parts is nothing new at CMPC. We have the experience and facilities to handle most any type of plastic molding job, large or small, and a nation-wide reputation for quality and service. All of which is just another good reason for discussing your plastics molding problems with a CMPC Development Engineer. Why not talk to him now? There's no obligation!

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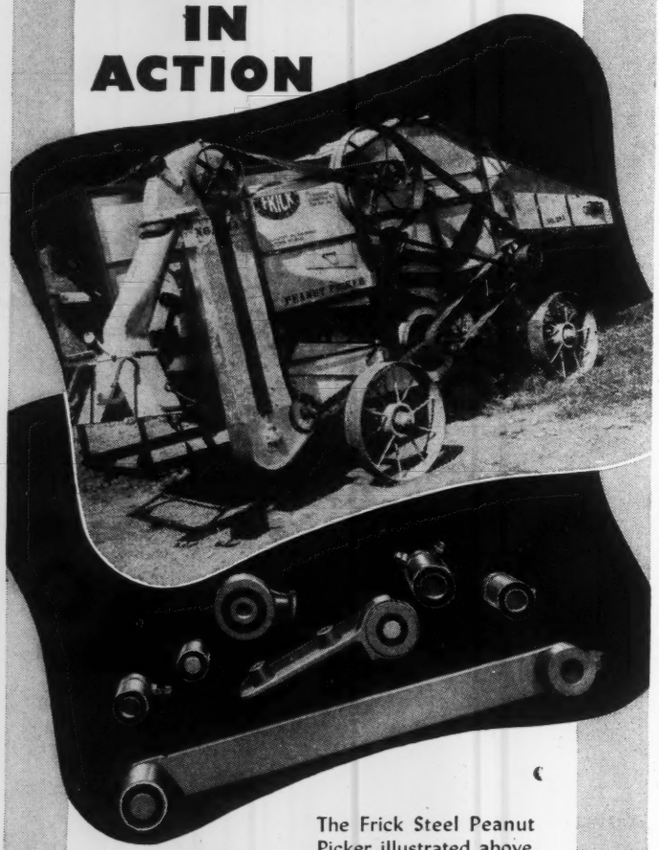
Torflex BEARINGS IN ACTION



The Frick Steel Peanut Picker illustrated above, uses 18 *Torflex* Bearings in various sizes for the ends of radius rods and pitman arms which actuate the screens.

Torflex Bearings are also used in other types of screen equipment, in rock and coal crushers and many other machines where the bearings are subject to dust conditions.

Torflex bearings require no lubrication, are practically without wear because there are no rubbing surfaces—they cushion shocks and absorb vibration. They are made in a wide variety of sizes and are applicable to all sorts of equipment.

If you have a wear or other problem in connection with any oscillating joints, we welcome the opportunity to furnish the answer.

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BUSINESS AND SALES BRIEFS

PREVIOUSLY executive vice president, Fred T. H. Youngman has succeeded R. Edson Emery as president of Jessop Steel Co., Washington, Pa. Mr. Youngman has been associated with the company for the past twenty-five years.

♦

H. H. Barrows of Industrial Equipment Co., 6435 Hamilton Ave., Detroit 2, has been named sales representative throughout the lower Michigan peninsula for the IMO Pump and Worm Gear Divisions of De Laval Steam Turbine Co.

♦

To handle its line of electric controls in northern California, Allen-Bradley Co. has appointed Campbell & George Co., 379 Brannon St., San Francisco 7.

♦

Appointment of the following representatives has been annouced by Philadelphia Gear Works Inc.: Leroy L. Handy, 6932 Cass Ave., Detroit 2, to represent the company in the Detroit area on all products including Limitorque valve controls; Atwood Machinery Co., 931 Santa Fe Ave., Los Angeles 21, to represent the company in southern California on every thing except Limitorque valve controls.

♦

Following the resignation of George C. Ewing, James F. Collins has been appointed field engineer and sales representative for Ajax Flexible Coupling Co. Inc., Westfield, N. Y. He will make his headquarters in the Statler Bldg., Boston 16.

♦

Marquette Metal Products Co. of Cleveland, manufacturer of precision parts and assemblies for the automotive and aviation industries since 1920, has been acquired by Curtiss-Wright Corp.

♦

Election of F. H. Hoge as president to succeed William Colemen has been announced by W. A. Jones Foundry & Machine Co., Chicago.

♦

Associated with the company since 1936, Thomas C. Ford has been named district manager of the Pittsburgh office of Electro Metallurgical Sales Corp.

♦

Formerly vice president in charge of sales and engineering for Smith Power Transmission Co., George E. Miller has been appointed assistant sales manager of the Machine Division sales department of Osborn Mfg. Co., Cleveland.

♦

Recently announced by The Kaydon Engineering Corp., Muskegon, Mich., is the appointment of Frank D. Clark as district engineer in Cleveland for the Ohio territory, and Claude C. Crosier as district engineer in Chicago for the Illinois and Wisconsin territory. Both were previously with the Bantam Bearings Division of the Torrington Co., South Bend, Indiana,

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ANNOUNCES

DIRECT FACTORY REPRESENTATION

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We'll help you solve your F.H.P. motor problems

IN YOUR OWN PLANT

Do you use or plan to use production-run quantities of F.H.P. motors (1/500 to 1/15 H.P.) or blowers in your products? Then our new policy means definite advantages to you. Now, our extensive motor technology, accumulated through years of F.H.P. motor engineering and manufacture, is available to you by *direct personal contact.* Our skilled, experienced factory engineers will bring to your own plant the latest and most complete technical information. Design, engineering and production problems can be solved without delay, on the spot. This new service may help you to improve product performance and lower costs. Write today, outlining your problem.

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BRIGGS & STRATTON ENGINES

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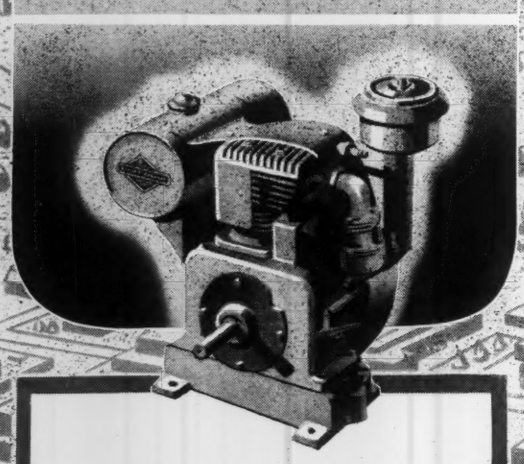

Manufacturers, dealers and users of gasoline powered appliances, farm machinery and industrial equipment know from experience that it pays to power with Briggs & Stratton 4-cycle, air-cooled engines.

Over two and one quarter million of these engines have demonstrated their ability to deliver dependable power under all operating conditions.

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Air-Cooled Power

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and handled sales of ball and roller bearings in the same territories they now cover for the Kaydon company.

♦

Appointment of N. A. Moerman as sales engineer has been made by the Potter Instrument Co., Flushing, N. Y., designer and manufacturer of high-speed electronic counting control equipment. Mr. Moerman had been at the Aberdeen Proving Grounds, Md., for the past six and a half years.

♦

Robert M. Zeller has joined the roll sales division of Aetna-Standard Engineering Co., Youngstown, O., and will serve in the capacity of roll engineer. He had been connected with Carpenter Steel Co., Reading, Pa.

♦

Previously territorial manager for The E. F. Houghton Co., Philadelphia, R. J. Swing has been named general sales manager of the industrial division of Monarch Aluminum Mfg. Co., Cleveland.

♦

Change to an incorporated company under the name of The Lindsay Corp. has been announced by the partnership of Lindsay, & Lindsay Chicago. No change in personnel has resulted.

♦

Fort Pitt Spring Co., Pittsburgh, has been acquired by H. K. Porter Co. Inc. Henry Miller will continue as general manager of the new division.

♦

According to an announcement by Globe Steel Tubes Co., Milwaukee, C. J. Bickler has been made manager of sales of the Los Angeles office. Mr. Bickler, who has been with the company since 1923, most recently served as assistant to the vice president in charge of sales at the Milwaukee office.

♦

Previously assistant to the general manager of Keystone Alloys Co., John E. Nipar has been named manager of sales and distribution for powdered metals and powder metallurgy parts.

♦

Johnson Rubber Co. has appointed the newly formed organization of Johnson-Sperry Co., Middlefield, O., as national sales representative to handle the entire sales of both the parent company in Middlefield and the Pawling, N. Y., branch. Heading the new company are Lugh M. Johnson and Pierce Sperry, both formerly with Johnson Rubber Co. Mr. Johnson was vice president and general manager, and Mr. Sperry, vice president and sales manager.

♦

Connected with the Berger Mfg. Division of Republic Steel Corp. for the past twenty years, Charles E. Howes has been named assistant manager of sales for the steel equipment division of Berger.

♦

Appointment of Julian Loebenstein as sales manager in its new Selenium Rectifier Division has been announced by Radio Receptor Co. Inc. Also announced is the appointment of the following sales agents for this division: E. T. Turney Jr., of Turney & Beale, 215-05 Twenty-seventh Ave., Bayside, N. Y., to cover the New York metropolitan area, New Jersey, and parts of Connecticut and Pennsylvania; J. E. Oliphant & Co., 505 Uhler Bldg., Marion, O., to cover the western half of Pennsyl-

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★ ★ ★

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Cleveland Tungsten has always manufactured all its tungsten products, including metal powder, rod, contacts and electrodes.

vania, and the western half of New York, Ohio, Michigan, Kentucky, West Virginia, Tennessee and Virginia.

♦

Herbert D. Rollo has been named New England district sales manager of the Wickwire Spencer Steel Division, Colorado Fuel & Iron Corp. Formerly wire rope sales engineer in Chicago and New York, Mr. Rollo now will be located at the New England district office at 80 Federal St., Boston 10.

♦

Moving of its manufacturing operations from Milwaukee to Cleveland has been announced by B-W Superchargers Inc., a Borg-Warner subsidiary. Facilities of the Pesco Products Co., another division of the parent organization, will be made available for continuing production.

♦

Formerly supervisor of sales engineering for Lear Inc. of Grand Rapids, Mich., Richard W. Weadon has been appointed sales manager of Yardeny Laboratories Inc. He has a background of twelve years in the electrical control and allied fields.

♦

Parts Mfg. Co., one of the few completely equipped furnace brazing plants on the West Coast, has been purchased by Ellinwood Industries and will be operated as a division of the company. Two other Los Angeles plants—National Machine Products and California Motor Cultivator Co. Ltd.—were purchased recently by Ellinwood Industries.

♦

Construction of a new plant at Watertown, Mass., for the manufacture of Hancock Products has been undertaken by Manning, Maxwell & Moore Inc. The sales department, with M. S. Palmer as department manager, will be moved from Bridgeport, Conn., as soon as the plant is erected.

♦

Recently in the Army, Robert C. Allen Jr. has been named manager of the Kansas City, Mo., factory branch of General Controls Co. He will serve users of automatic pressure, temperature and flow controls in Missouri, Kansas, eastern Nebraska and western Idaho.

♦

J. Coburn Musser, vice president since 1939, has been elected president of Eberhard Faber Pencil Co., Brooklyn, N. Y. He is also president of Eberhard Faber Corp.

♦

Announced by Dynamic Air Engineering Inc., Los Angeles, is the appointment of Elmer Lehmkuhl as sales manager. Previously he had been connected with Propellair Inc. and Master Electric Co., Dayton, O.

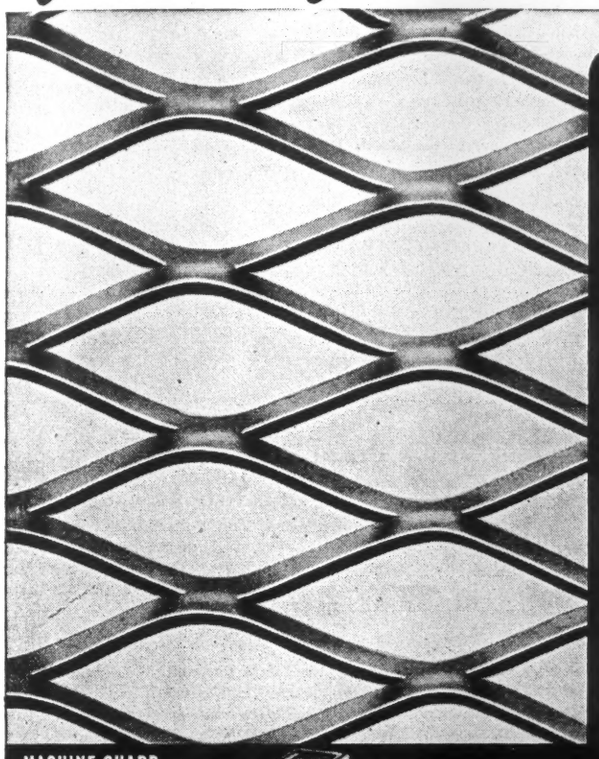
♦

Under the management of Thomas A. Card and Richard V. Cook, The Faxfilm Co. has been formed at 1220 West Sixth St., Cleveland, in order to meet the demand for the Faxfilm method of surface examination invented by Rex D. McDill. Mr. McDill will act in an advisory capacity.

♦

Connected with the company since 1936, Albert H. Charlton has been appointed sales manager of the Aluminum Division of Reynolds Metals Co., and will make his headquarters in Louisville, Ky. Prior to his appointment, he had been eastern sales manager for this division in New York.

light weight with STRENGTH

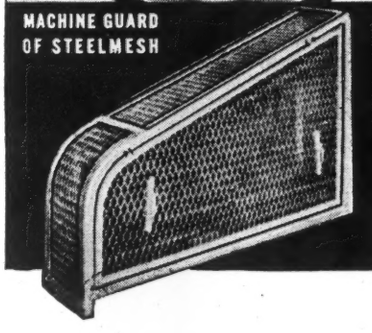


Penmetal Steelmesh

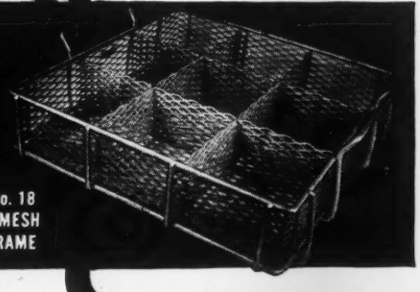
EXPANDED METAL

One square foot of steel plate is expanded to become four to five square feet of Penmetal Steelmesh. No steel waste. The truss-like formation is actually more rigid than the original plate. By using Penmetal Steelmesh for certain parts, a household article has just been designed with a saving of 25% in the total weight. Can be cut, shaped and arc or resistance welded without raveling or joint failures.

Investigate the advantages of Penmetal Steelmesh in the fabrication of your product. *Write for catalog and samples.*



MACHINE GUARD OF STEELMESH



BASKET OF ½" No. 18 FLATTENED STEELMESH WELDED TO ROD FRAME

APPROXIMATE SIZES, DIMENSIONS AND WEIGHTS

Style Designation	STANDARD STEELMESH: U. S. Standard Gauge Steel Used	Weight in Lbs. Per Sq. Ft.		Stock Sizes of Sheets	Size of Mesh from Centers of Bridges		FLATTENED STEELMESH: Weight in Lbs. Per Sq. Ft.		Stock Sizes of Sheets	Size of Mesh from Centers of Bridges	
		Plain	Galv.		Width	Length	Plain	Galv.		Width	Length
½"–#20	20	.50	.63	3′ & 6′ x 8′	.45″	1.2″	.47	.63	3′ & 4′ x 8′	.46″	1.28″
½"–#18	18	.74	.91	3′–4′ & 6′ x 8′	.45″	1.2″	.70	.91	3′ & 4′ x 8′	.46″	1.28″
½"–#16	18	.81	.97	4′ x 8′	.45″	1.2″	.77	.97	4′ x 8′	.46″	1.28″
¾"–#16	16	.50	.59	3′–4′ & 6′ x 8′	.95″	2.0″	.47	.59	3′ & 4′ x 8′	.97″	2.13″
¾"–#13	13	.80	.92	3′–4′ & 6′ x 8′	.95″	2.0″	.76	.92	3′ & 4′ x 8′	.97″	2.13″
1½"–#18	18	.20	.25	2′ & 4′ x 8′	1.34″	3.0″	.....	.....	.....	.....	.....
1½"–#16	16	.40	.48	2′ & 4′ x 8′	1.34″	3.0″	.38	.48	2′ & 4′ x 8′	1.34″	3.20″
1½"–#13	13	.60	.68	4′ & 6′ x 8′	1.34″	3.0″	.57	.68	3′ & 4′ x 8′	1.34″	3.20″
1½"–#10	13	.79	.89	4′ & 6′ x 8′	1.34″	3.0″	.75	.89	3′ & 4′ x 8′	1.34″	3.20″

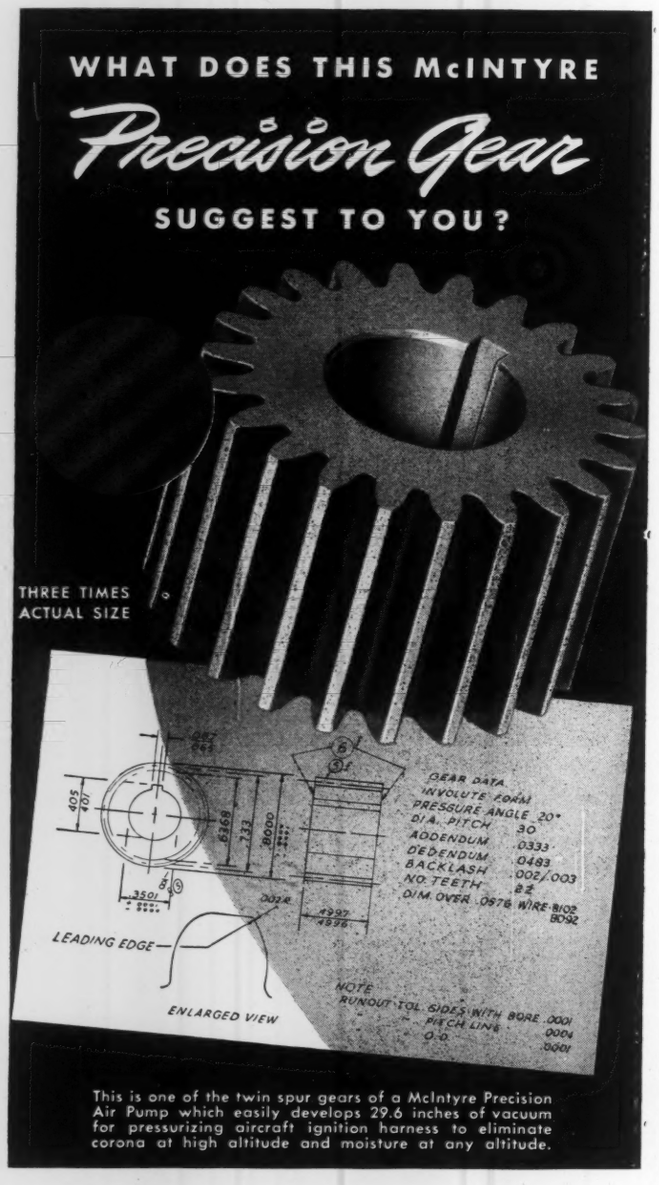
PENN METAL COMPANY, INC.

Dept. 30, Parkersburg, W. Va.

District Sales Offices

BOSTON • NEW YORK • PHILADELPHIA • CHICAGO • DETROIT • PARKERSBURG, W. VA
LOS ANGELES • SAN FRANCISCO • DALLAS

METAL MARK Penmetal 1869 OF QUALITY



This is one of the twin spur gears of a McIntyre Precision Air Pump which easily develops 29.6 inches of vacuum for pressurizing aircraft ignition harness to eliminate corona at high altitude and moisture at any altitude.

HOW TO GET BETTER GEARS AT ORDINARY PRICES

With machining methods capable of making surfaces flat to one light band and holding vital dimensions to plus or minus .000025", The McIntyre Co. applies tool-room tolerances to the mass production of spur gears.

That's why it is routine instead of special production when the illustrated gear has its sides lapped within .00005" of parallelism . . . its hole and O.D. ground to .0001" tolerance and runout . . . its teeth shaped and shaved to a pitch line runout of .0004".

For spur gears up to 10" O.D., to tolerances in tenths and split tenths in any material, specify McIntyre Precision Gears. Submit specifications for estimates — today. The McIntyre Co., 15 Riverdale Ave., Newton 58, Mass.

THE McINTYRE CO.
(FORMERLY ZENITH ASSOCIATES)
PUMPS AND FLUID MOTORS

THE ULTIMATE IN PRECISION IDENTIFIED BY THE LIGHT BAND

Meetings and Expositions

Feb. 25-28—

American Institute of Mining & Metallurgical Engineers. Annual meeting to be held in Chicago. Additional information may be obtained from headquarters of the society at 29 West 39th St., New York. Frank T. Sisco is secretary of the Metals Division.

Feb. 25-March 1—

American Society for Testing Materials. Spring meeting and committee week to be held in Pittsburgh. Additional information may be obtained from Robert Painter, assistant to the secretary, at headquarters of the society at 260 South Broad St., Philadelphia 2.

Feb. 25-March 2—

Twentieth Exposition of Chemical Industries to be held at Grand Central Palace, New York 17. Charles F. Roth, at the same address, is manager of the exposition.

March 20-22—

Chicago Technical Societies Council. Chicago production show to be held at the Stevens Hotel, Chicago. Paul A. Jenkins, 53 West Jackson Blvd., Chicago 4, is executive secretary.

April 1-3—

American Society of Mechanical Engineers. Spring meeting to be held at Chattanooga, Tenn. Additional information may be obtained from headquarters of the society at 29 West 39th St., New York. C. E. Davies is secretary.

April 3-5—

Society of Automotive Engineers Inc. National aeronautic meeting (Spring) to be held at Hotel New Yorker, New York. John A. C. Warner, 29 West 39th St., New York 18, is secretary and general manager.

April 10-13—

Electrochemical Society Inc. Spring congress to be held at Hotel Tutwiler, Birmingham, Ala. Colin G. Fink, 3000 Broadway, New York 27, is secretary.

April 22-27—

Society of the Plastics Industry Inc. First national plastics exposition to be held at Grand Central Palace, New York 17. W. T. Cruse, 295 Madison Ave., New York 17, is executive vice president.

April 27-May 19—

Products of Tomorrow Exposition to be held at Chicago Coliseum group of buildings, Chicago. Marcus W. Hinson, 1513 South Wabash Ave., Chicago, is in charge of planning and general management of the exposition.

April 28-May 1—

American Ceramic Society Inc. Forty-eighth annual meeting to be held at Hotel Statler, Buffalo. Ross C. Purdy, 2525 North High St., Columbus 2, O., is general secretary.

May 6-10—

American Foundrymen's Association. Foundry congress and show to be held at Cleveland Auditorium, Cleveland. Wm. W. Maloney, 222 West Adams St., Chicago 6, is secretary.

June 3-5—

American Gear Manufacturers Association. Thirtieth annual meeting to be held at The Homestead, Hot Springs, Va. Newbold C. Goin, Empire Bldg., Pittsburgh 22, is executive secretary.

June 3-6—

American Society of Mechanical Engineers. Aviation Division meeting to be held at Los Angeles. Additional information may be obtained from headquarters of the society at 29 West 39th St., New York. C. E. Davies is secretary.

June 12-15—

American Society of Mechanical Engineers. Oil and Gas Power Division meeting at Milwaukee. Additional information may be obtained from C. E. Davies, secretary of the society, at the headquarters at 29 West 39th St., New York.

Announcing

"CLUTCH HEADS" BY NATIONAL SCREW

To serve industry still better with the most complete line of fasteners made by one manufacturer, we now offer the new and modern CLUTCH HEAD SCREWS.

More speed, added safety and longer tool life combine to reduce costs when Clutch Heads are used. Can be driven with a conventional screw driver or a special type driver. "Lock-On" feature permits easy one-handed reaching, driving and withdrawing.

In addition to the most complete line of staple fasteners made, we produce the following patented fasteners:

Phillips Recessed Screws	**Lok-Thred Studs**
Laminar Flow Screws	**Rosán Fasteners**
Marsden Lock Nuts	**Scrivets**
Huglock Nuts	**Hi-Shear Rivets**
Dynamic Lock Nuts	**Lock Washer Assemblies**
Drake Lock Nuts	**Clutch Head Screws**

National
HEADED AND THREADED
PRODUCTS

Consult with us for information or advice on any fastener question.

THE NATIONAL SCREW & MFG. CO., CLEVELAND 4, O.